Chapter 3

GIS In American High Schools: A National Survey

Introduction

The review of the related literature in the previous chapter illustrates the scarcity of research on GIS implementation and effectiveness at the secondary school level in the United States. This chapter and the two that follow describe and interpret the results of this dissertation research conducted to answer questions on implementation and effectiveness.

A survey was employed to *describe* the extent to which GIS technology and methods are being implemented. To *explain* how GIS technology and methods are being implemented in secondary education was addressed by the survey as well as by a series of experiments and case studies in three high schools. Experiments and case studies were conducted to *assess* the effects of GIS-based lesson modules using GIS tools on teaching and on the acquisition of standards-based geographic content and skills of selected teachers and students in three high schools. Figure 3.1 illustrates the linkages between research questions and the methods used to answer those questions.

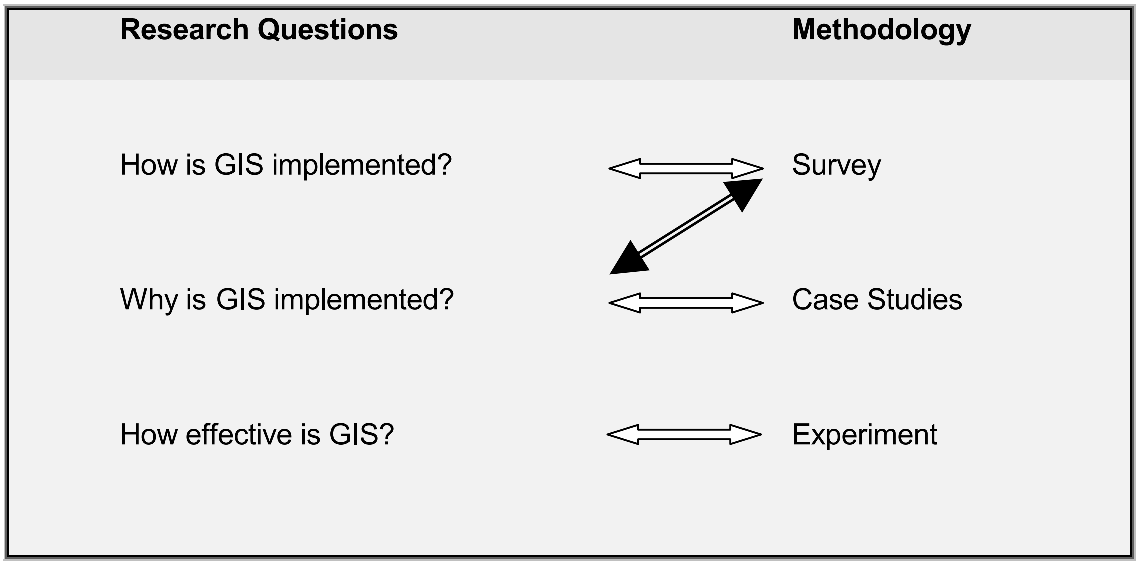

Figure 3.1. Diagram of Research Questions and Methodology.

Three distinct methodologies are used: (1) survey; (2) experiment; and (3) case study. The study includes both predictive (experiments) and descriptive (case studies) elements, and generates both qualitative and quantitative data. The combination of three methods and the differences of data types they employ supports the "multiple triangulation" strategy advocated by Denzin (1989) and others, in order to reduce intrinsic bias that may occur with a single-data and single-method approach. Bednarz (1995) called for a mixing of qualitative and quantitative research to develop a picture of complex relationships among students, teachers, and learning to adequately evaluate GIS in education, which is what this study does.

The research was conducted in five stages: (1) develop and test the survey instrument; (2) conduct a by-mail cross-sectional survey to 1,520 teachers; (3) conduct a series of experiments in three schools; (4) conduct case studies in three schools; and (5) perform data analysis. Steps (3) and (4) were conducted concurrently because the case studies and experiments took place in the same high schools.

The three populations examined were: (1) teachers who responded to the national GIS-in-education survey; (2) students from the three experimental and case study schools; and (3) teachers from these same three schools.

This chapter describes how I designed and conducted a national survey to understand the *implementation* of GIS in secondary education. Next, I analyze the results of this survey in order to answer two research questions. First, it will *describe* the extent to which GIS technology and methods are being implemented in secondary education in the United States, including the specific disciplines, extent in the curriculum, and the spatial and temporal pattern of adoption. Second, it will *explain* how GIS technology and methods are being implemented in secondary education, analyzing technological, methodological, instructional, sociological, and behavioral barriers and catalysts.

Conducting the National Survey

The survey sought to answer two research questions at the national level: (1) *how* secondary teachers are using GIS in their curricula, and (2) *why* they are using GIS in their curricula. The most expedient and accurate method of gathering answers to these questions was a national, by-mail, survey. I rejected a telephone survey for several reasons. First, the telephone numbers of teachers using GIS was not available and would require extensive research to compile. Second, even if the numbers were to be compiled, numerous long-distance calls would greatly add to the time and expense of the research project. Third, several open-ended descriptive and attitudinal questions were essential in the survey. These required several minutes of the teacher's time to consider and were less suitable to obtain via a telephone call. Fourth, a telephone survey was rejected because of the small probability of telephoning the teacher during his or her planning period when the teacher was not teaching class, requiring additional followup with no appreciable gain in response. I concluded that the mail method would be able to achieve the most accurate and consistent results, with the highest return rate for the least cost. Furthermore, "questionnaire surveys…are particularly useful where there are few base data available" (Stimpson 1996: 123). As demonstrated in the previous chapter, there are no base data about the use of GIS throughout the nation's secondary schools.

Designing the Survey Instrument

I employed several criteria in designing the survey instrument. First, the questionnaire was targeted to teachers who *owned* a GIS packageXno assumption was made as to whether the teacher was actually *using* GIS. Data were equally important both if the teacher was using GIS and if the teacher was *not* using GIS. Because I did not assume that teachers were using GIS in all of their classes, they were asked two questions: (1) the name of the subjects they taught, and (2) the name of the subjects in which they used GIS. To increase the probability that the questionnaire would be returned, the questionnaire was designed so that the respondent could complete it in 15 minutes or less. This limited the survey to 33 questions. Five questions required the teacher to write a few sentences, but each respondent was only required to answer four, since one was an "either-or" pair of questions. To minimize the amount of writing required, the five essay questions were formulated as "completer" or "stem" statements so that a respondent would only have to fill in the remainder of the sentence. A total of 28 questions could be answered by circling a preprinted answer. Eight questions included space to "fill-in-the-blank" with additional comments.

The survey included five categories of questions. To understand *how* teachers are using GIS in their classrooms, questions included the grade levels where GIS is being implemented, the subjects in which GIS is being implemented, the year of GIS software acquisition, the year of GIS implementation, and the degree of implementation. There were also questions addressing the degree of implementation, the number of teachers involved in GIS at the school, the percentage of students exposed to GIS in the school, and a description of a GIS-based lesson.

To understand *why* teachers are using GIS, questions were asked about the number of hours the teachers spent in formal training classes, the number of hours per week spent outside of class time on GIS, the planned use of GIS in the following academic year, and why the teacher decided to use GIS, or why the teacher is not using GIS, as the case may be.

A list of perceived benefits and constraints was presented with a Likert scale for each response, based on the review of the related literature (discussed in the previous chapter), and from interviews with teachers in a pilot study group (discussed below). Perceived benefits included linkages to standards, enhanced learning, data analysis, employment skills, team learning, real-world relevance, integration of subjects, community partnerships, and enhanced motivation. Perceived constraints included the complexity of GIS software, monetary cost, inaccessible and insufficient computers, lack of time to develop lessons, insufficient technical and administrative support, short class periods, lack of data, lack of geographic skills, and variable skill levels. Space was provided for teachers to list others if they chose.

To understand both *how* and *why* teachers are using GIS, respondents were asked what was the most important thing that would improve their use of GIS in teaching, administrative support, the most significant thing accomplished with GIS in the past year, and whether GIS can make a significant contribution to a student's learning. Questions were asked about the teachers' backgrounds, classes, and schools.

To assess the spatial pattern of GIS diffusion in secondary education, a question was included about where a teacher had first been trained in GIS. Surveying the computer facilities and access at each school was included for analyzing the factors affecting the use of GIS software.

Pilot Testing the Survey

Following Jaeger (1997), the questions were reviewed and assessed by an expert panel and pilot-tested with a small group, in order to assure that the survey questionnaire met the goals of the research and would be understandable to teachers.

The panel consisted of three members of the Environmental Systems Research Institute's (ESRI) K-12 education team, the *Idrisi* K-12 education representative, and the *MapInfo* K-12 education representative. For nearly a decade, they have been among the most active trainers of teachers in the nation in the use of GIS, creating data sets specifically for the educational community, developing GIS-based lesson modules, and creating workbooks and tutorials. After discussing the goals of the project with the group on the telephone, I sent them the questionnaire in July, 1998.

The pilot group consisted of the participants in the first national GIS summer institute, which was sponsored by Southwest Texas State University, the National Council for Geographic Education, and the Geographic Education National Implementation Project, in July 1998. In attendance were teachers from Grades 2 through college-level who applied to the institute to receive their first training or to further their previous training in GIS technology and methods. This group was chosen because it largely represented the same population as the sampling frameXhigh school teachers who have obtained GIS software. I also considered responses from the non-high-school teachers at the institute. Even though they did not represent the final surveyed population, their comments were helpful and valuable. Several of these teachers had previously worked at the secondary level.

The expert panel and pilot group were asked to complete the survey and comment on its length, meaning, wording, and clarity using the questionnaire in Figure 3.2. They were interviewed using these same questions and asked if they believed the survey would meet the goals of the research. The survey questionnaire was refined based on responses from the expert panel and pilot test group (Appendix A.2).

For GIS Trainers and Teachers Involved with Testing the Survey

1) How long did it take you to fill out this survey? _________ minutes

2) Circle your opinion of the time the survey required:

1	2	3	4	5
Too little				Too much

3) Do you feel that the survey, as written, will be completed by most teachers who use GIS?

Yes No

4) Can you suggest ways to improve the clarity, organization, response rate, or effectiveness of the survey?

Figure 3.2. Questionnaire for Expert Panel and Pilot Test Group.

Obtaining the Population for the Survey

Because the research population was secondary teachers using GIS, a list of teachers using GIS in the curriculum was required. The best approximation to this was a list of teachers whose schools owned a GIS software packageXthey either have purchased or have been donated this type of software.

Numerous brands of GIS software exist (Appendix A.4). The literature review in Chapter 2 and an analysis of GIS listserves on the Internet both indicated that three software packages had been implemented in education more than any other as of 1998. These were *Idrisi*, by the Clark Labs at Clark University of Worcester, Massachusetts, *MapInfo*, by MapInfo Corporation of Chicago, Illinois, and *ArcView*, by Environmental Systems Research Institute (ESRI), Incorporated, of Redlands, California.

A listing of teachers owning GIS software was procured from these three sources, and became the sampling frame for the survey. I requested that the K-12 educational representatives at each of these organizations edit their lists of software owners to obtain secondary schools in the USA. In the case of MapInfo, the K-12 educational market was assigned to a company named Encompass Technologies. These three lists were obtained with the agreement that the lists would be used solely for educational purposes, that the respondents' answers would be kept anonymous, and that the names and addresses from any list would not be shared with the producers of another list. These lists were delivered in various spreadsheet and database formats via E-mail. They were sorted in random fashion and contained one record per GIS owner. Each record included a teacher's name or placeholder, school name, and address.

Preparing the Sampling List

Upon receiving the listings, I examined each to determine if more than one record for each teacher's name existed. I removed duplicates from the possible records that could be selected for the random sample. Duplicates across lists were treated in the same manner; in other words, if a teacher was using both *MapInfo* and *ArcView*, and therefore appeared in each list, that teacher could only be selected once in the sampling frame.

Even though the lists were requested for secondary schools in the U.S., an analysis of each list revealed several non-qualifying organizations. All records outside the United States were removed, as was any record for an elementary school. Middle schools, which usually are Grades 6, 7, and 8, or a subset thereof, were removed. Junior high schools were retained as they usually include Grade 9 students, which were within the scope of the study. I eliminated non-educational institutions and colleges and universities. Listings of American K-12 schools on the Internet site of the American School Directory (*http://www.asd.com*) helped identify qualifying schools where the name of the school did not indicate the grade level of its students; for example, "Colorado Academy" and "Logan School." On the few occasions where the school was not listed online, the school was retained in the list.

Next, I edited the lists so that the data fields would be consistent for the purpose of constructing mailing labels. A field was added to identify the type of software that was being used by the teachers listed. The lists were then combined into one list, with *Idrisi* first, followed by *MapInfo*, and ending with *ArcView,* so that each school had an equal chance of being surveyed, regardless of the software type used. The combined list contained 1,826 records, or separate schools, that owned GIS software, and was numbered from 1 to 1826 for selecting the random sample.

Selecting the Random Sample

Next, I constructed the sample from the combined listing of American secondary schools. Krejcie and Morgan (1970) and Leedy (1997) specify that for a sampling frame of 3,000, at least 341 in the sample are required for an unbiased survey. Estimating the response rate at 25% dictated that surveys be sent to 341/.25, or 1,364 schools. Allowing for a lower response rate, owing to the fact that the respondents were busy, full-time teachers, the random sample was conducted until 1,528 schools were selected.

Because one of the research goals was to understand the attitudes and strategies of those actually using GIS software, the survey needed to be directed to that teacher in each school. For this reason, I retained the original names in the mailing list, rather than replacing them with "GIS Teacher" or "Geography Teacher" or "Science Teacher." Because mailing lists such as these have inherent error, and because of the possibility that the teacher may have changed schools, a message was included that instructed the recipient to route the survey to the person at the school using GIS. I did not want responses from the person who simply ordered the software, the computer systems administrator, or other administrator. In the rare instances where it could be determined that the principal, financial coordinator, or other administrator was named on the mailing list instead of a teacher, the survey was sent to the "GIS Instructor" at the school. The number of surveys where this occurred was 36, or 2.4%. I decided that telephoning these schools to obtain the names of the GIS users would not be worthwhile for such a low percentage. Furthermore, it was possible that many teachers were not using GIS, despite being recipients of GIS software at some time in the past.

Only one survey was sent to each school. If more than one teacher was active with GIS in the school, the survey could be answered by any one of these teachers.

Because the literature review revealed that GIS is most often used by only one teacher within a school, I judged the amount of potential data lost by not sending multiple surveys to be minimal. In addition, one of the survey's goals was to assess the characteristics of the schools where GIS was implemented. Sending multiple surveys to a single school would have skewed the data and made it difficult to interpret. The survey was mailed to a random sample of the schools in the sampling frame. The complete survey is provided as Appendix A.3.

A total of 422 of 1,520 surveys were returned, yielding a 28% response rate. In addition, nine surveys were received from one school district after the initial recipient copied the survey and sent it to other teachers using GIS. Because including these surveys would have biased the sample, they were not tabulated. Of the 422 surveys, 13 were discarded because they were returned by GIS users that were not high school teachers and did not fit the population. Therefore, 409 surveys were analyzed. The necessary number of completed surveys was achieved.

Tabulating the Survey Data

Data were tabulated even if the respondent did not complete the entire questionnaire. If multiple answers were circled on the questionnaire, these answers were tabulated. Therefore, sums for several questions totaled more than the number of questionnaires received. The one exception to this coding scheme was the degree of GIS implementation. Since this question was a ranking from the lowest degree of GIS implementation to the highest, I recorded the response indicating the highest degree of implementation.

I made no assumptions and did not tabulate any item that had not been filled in by a respondent, even when the other responses made it obvious what a specific answer should have been. When comparing the year when GIS software was acquired to the year it was implemented, I considered only those respondents who had answered both questions, and did not consider obviously erroneous responses that indicated that GIS had been *implemented* before it was *obtained*. I calculated "not using GIS yet" to be equivalent to one additional academic year of delay for teachers who had acquired GIS during the 1997-98 school year. In other words, if the respondent had acquired GIS in 1997 or 1998 but had not begun using it as of the time of the survey, I calculated the delay for be *at least* 1 to 2 years for that respondent. The complete survey results are provided in Appendix A.3.

Analyzing the Survey Results

Survey responses were analyzed and grouped into subject headings. One subject was a spatial and temporal analysis of the schools that owned GIS software, and schools that responded to the survey. *ArcView* GIS version 3.1 was used to create maps to analyze the geographic location and the spatial diffusion of GIS as an innovation and whether the respondent was using GIS. The resulting spatial pattern showed past GIS training activity and identified gaps. The temporal pattern indicated the nature and severity of impediments and catalysts to GIS adoption, and was tested against the model of GIS implementation proposed by Audet and Paris (1997). This pattern and the survey results were also analyzed according to Rogers' (1995) diffusion of innovation theory, Caffarella and Hall's (1999) innovation decision model, social interactionism, and four predictors of educational GIS use.

I analyzed responses about the extent to which the school is using GIS technology and methods during the semester in which the survey was received according to the continuum in Table 3.1. Survey results were classified by an ordinal variable, that ranged from non-adoption (not using GIS) to full adoption (using GIS in more than one lesson in more than one class) of the technology. Results were also analyzed according to a nominal variable with two possible values—adoption and nonadoption—with adoption as anything above and including demonstrating GIS in the classroom.

Table 3.1. Categories Representing the Degree of GIS Implementation.

Adoption or Nonadoption	Implementation Level	Description
Nonadoption	Lowest	The school owns GIS software, but it is not being used.
Nonadoption		GIS is being investigated by one or more teachers at the school for its potential merit and means of implementation, but it is not being used.
Adoption		GIS is being used for demonstration purposes only. This represents the lowest level of implementation.
Adoption		Teachers use GIS to create curricular materials.
Adoption		GIS is used in one lesson in one class.
Adoption		GIS is used in one lesson in more than one class.
Adoption		GIS is used in more than one lesson in one class.
Adoption	Highest	GIS is used in more than one lesson in more than one class.

Survey data were analyzed concerning the demographic characteristics of the schools and classes, the subjects taught by the responding teachers, the subjects in which GIS is used, and the instructional methods by which GIS is taught. The methods by which the teacher learned about the technology were analyzed. The teacher was asked where he or she was *first* trained, since the literature review implied that challenges in using GIS would mean that ongoing training would be likely. I categorized the responses into state geographic alliance summer institutes, other training sponsored by state geographic alliances, school district inservices, GIS or other geography-related private companies, computer companies, other private companies, universities, government agencies, or instances where the teacher trained himself or herself.

I created a taxonomy based on the responses to the teacher's identified limitations and strengths of the technology. The utility of the technology was assessed from direct responses by the teachers, and deduced from their plans to use GIS in the future. The respondent indicated why he or she *is* or *is not* using GIS, as the case may be. GIS-based lesson modules described by teachers and other comments were compared to traditional and constructivist orientations according to Oblinger and Maruyama's (1996) model of the social organization of classrooms.

An analysis of the amount of computer, training, and administrative support that teachers have for GIS was made to determine the relationship of the amount of support to attitudes and extent of use. Chi-square tests on nominal (frequency) data were run to determine the difference between adopters and nonadopters for the length of teaching service, student-computer ratio, the date GIS software was obtained, the number of GIS-using teachers in the school, computer operating system, technical and administrative support, and professional activity of the teacher. Chi-square tests were used because the measures were ordinal and because two samples of teachers were compared. These tests are nonparametric, used because the sample values from the survey could not be assumed to have a normal distribution. A high chi-square value ($P<.05$) indicates that there is a large amount of difference between the observed and the expected frequencies, and would suggest that the null hypothesis can be rejected—that there *is* a difference in these characteristics between adopters and nonadopters. Student's *t*-tests were run to test for significant differences between the constraints perceived by adopters and nonadopters. A correlation and multiple regression were conducted to determine the chief contributing factors to a teacher's use of GIS. I used Microsoft *Excel 97* spreadsheet software and *Stata 6.0* statistical software for analysis.

Limitations of the Survey

Survey responses were assessed and tabulated by individual question. As with any survey, it is acknowledged that some slippage may have occurred between the desired conceptual variables, and the surrogate variables that were actually measured. For example, one conceptual variable was the degree of professional activity of a teacher. The surrogate variable to measure this was the number of educational conferences that the teacher attends each year.

Because one of the survey's aims was to determine the status of GIS implementation in high schools, data were needed both if the teacher *was* using GIS and equally important if the teacher *was not* using GIS. However, some teachers skipped large portions of the questionnaire after stating that they did not use GIS at the present time. Others returned the survey with nothing marked, indicating AI am not using GIS≅ on the cover sheet. This means that survey results reflect more of the opinions of the teachers using GIS, and less of those who do not. However, since most of the questions pertained to those who *do* use GIS, this omission of information by some nonadopters does not negate the usefulness of these data to address how and why GIS is implemented in secondary education.

Analysis of Survey Results

School Type, Enrollment, and Class Size

Teachers interested in GIS are largely in moderate-sized public high schools. Nearly nine out of ten of survey respondents teach in public high schools (n=392) with over half of the respondents responding from schools between 500 and 1,999 students (n=370, Figure 3.3 and Table 3.2). Furthermore, the average class size taught by these teachers is standardXover 59% of the classes contain 21 to 30 students (n=353, Table 3.3).

Educational technology researchers have identified inequalities in schools that computers might exacerbate (Page 1998). The national survey indicates that rather than being implemented in small, private schools with presumed advantages such as funds for technology and small class sizes, GIS is being used primarily in average-sized public schools in traditional science and geography curricula.

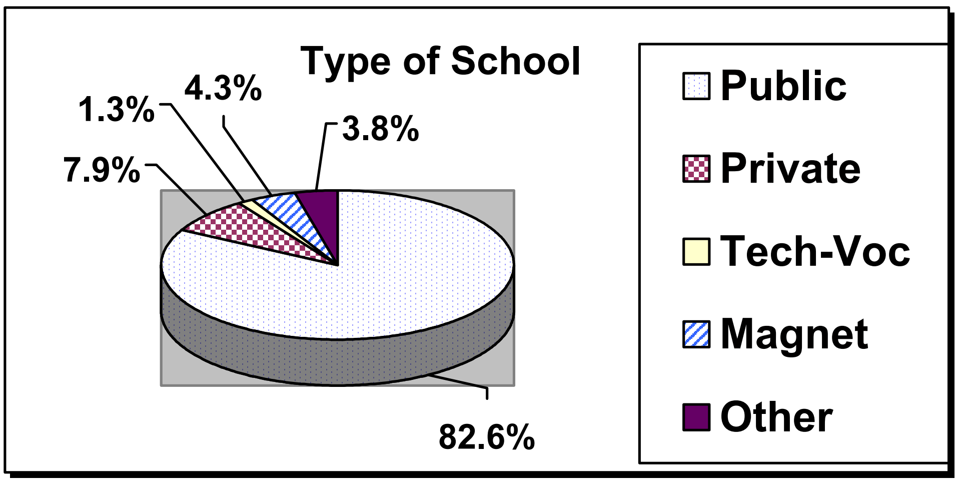

Figure 3.3. Type of School.

Table 3.2. School Enrollment.

Enrollment	Responses (n=370)	Percent of Total
< 250	48	12.97
250X499	43	11.62
500X999	99	26.76
1000X1999	120	32.43
2000X2999	40	10.81
> 3000	20	5.41

Table 3.3. Class Size.

Class Size	Responses (n=353)	Percent of Total
< 10	15	4.25
11X20	99	28.05
21X30	209	59.21
> 30	30	8.50

Characteristics of Teachers

Teachers interested in GIS are highly educated. Over 76% have a Master's or Ph.D. degree. It follows that highly educated teachers must have been teaching for a longer period of time. Indeed, over 60% of respondents have been teaching at least 15 years, and over 45% have been teaching at least 20 years (Table 3.4). Only 23 respondents are in their first three years of teaching.

Table 3.4. Years of Teaching Service.

Years of Teaching Service	Responses (n=372)	Percent of Total
< 3	23	6.18
3X5	26	6.99
6X9	44	11.83
10X14	53	14.25
15X19	57	15.32
20X29	125	33.60
> 30	44	11.82

These data indicate that GIS is a complex, advanced tool, preferred by teachers who have the educational background necessary to implement it. Veteran teachers also may have more time to devote to a long-term project such as GIS, because they have already established a set of lessons, each of which takes less time to implement. New teachers, by contrast, must spend time gathering materials, developing curricula, and creating tests for the first time for each unit. The discovery that GIS is used primarily by veteran teachers supports a survey of 15,000 teachers (Education Week 1999), which found that "teachers who have been in the classroom five years or fewer are no more likely to use digital content than those who have been teaching more than 20 years."

According to the National Center for Education Statistics, 26% of American secondary teachers are 50 years old or older (Zehr 1997). Most teachers of this age have approximately 25 years of teaching experience behind them. The survey respondents using GIS are older and more experienced than the general population of secondary teachers. Clearly, something motivates veteran teachers to use GIS. The reasons these teachers cite for using GIS will be explored in a later section. Teachers who have been in schools over 20 years must consider GIS to have real benefits—they have weathered enough fads to be able to spot one.

A chi-square test was run on the years of teaching to determine if there is a significant difference between adopters and nonadopters (Table 3.5). The null hypothesis is that the two groups are equivalent, and chi-square measures how much they depart from equivalency.

The difference between the two groups is not significant at P=.05. Adopters are not teaching significantly longer than nonadopters, but both groups have been teaching longer than the general population of teachers.

Table 3.5. Years of Teaching, Adopters vs. Nonadopters, Chi-square test.

Years of Teaching Service	Do Not Use GIS	Use GIS	Total
< 3	9 5.88%	13 6.40%	22 6.18%
3X5	18 11.76%	8 3.94%	26 7.30%
6X9	16 10.46%	26 12.81%	42 11.80%
10X14	19 12.42%	31 15.27%	50 14.04%
15X19	26 16.99%	75 36.95%	55 15.45%
20X29	46 30.07%	21 10.34%	121 33.99%
30 and over	19 12.42%	21 10.34%	40 11.24%
Total	153 100.00%	203 100.00%	356 100.00%
Pearson chi –square χ^2 (6) = 10.2277 P = 0.115			

Survey results confirm the research of Bednarz and Audet (1999), which found that most geographic technology training has been aimed at inservice teachers, rather than preservice teachers. Otherwise, more teachers in their first three years of teaching would be using GIS, or at least be demonstrating it in class. Results also support a survey of 416 teacher-training institutions that suggested that teachers are not being adequately trained to *apply* technology effectively to their teaching strategies (Milken Exchange and the International Society for Technology in Education 1999).

One faculty member in a college of education commented:

> "I have been working for several years with faculty at one of the nation's largest teacher training programs in the country. […] We have found that the future teachers get no systematic and purposeful training in any aspect of the use of computers, unless they specifically enroll in a computer course. Thus, we have to teach basics of computer use before we can introduce software packages, and you can imagine how long it takes to get to a point that the students can evaluate programs for use in the classroom. It seems that any effort to reach teachers regarding GIS would be valuable if it teaches critical thinking about the use of computers in learning environments" (EDGIS-L 1997).

To address these needs, the first national GIS for teacher educators was held at Roger Williams University in January 1999. This was designed to begin field testing implementation models for preservice educators, and could be the seed from which begins a growth of GIS in preservice education across the country.

To embark on a long-term program of learning about and implementing a complex system such as GIS in the curriculum, teachers must be highly motivated, willing to take risks, and not afraid to experiment with new strategies. Mertz (1987) identified teachers with these characteristics as "excellent" teachers. They spend time outside school to reflect on their teaching and share ideas with others. These data, together with the descriptions these teachers provided about their GIS-based lessons, support Wigginton's research (1985) that the best teachers are "deeply involved." It also confirms a nationwide survey by Sheingold and Hadley who found that the majority of computer-using teachers had at least 13 years experience, were largely self-taught, and devoted considerable time, funds, and effort to their extensive use of computers (Hardy 1998). Indeed, GIS-using teachers tend to be active—nearly all (87.8%; n=353) attend one or more educational conferences each year, and nearly one-third (32.9%) participate in at least three educational conferences annually. A chi-square test conducted on conference attendance for adopters versus nonadopters found a significant difference between the two groups (chi-square = 12.07; P = 0.017).

Subjects Taught

Two questions about disciplines were included on the survey. One asked the subjects taught, and the second asked, "If you use GIS, in which subjects do you do so?" Both indicate that although GIS is most often taught in geography departments at the college level, at the secondary level, educators *interested* in GIS are more often science teachers (36.2%) than geography teachers (16.9%)(Figure 3.4). For decades, educators such as Schwab (1966) have advocated that high school science be taught as inquiry, a method of investigation that relies on "conceptual innovation, proceeds through uncertainty and failure, and results in knowledge that is contingent, dubitable, and hard to come by." Science teachers may be traditionally more willing to experiment with new technology and methods, particularly with a complex, open-ended system such as GIS. The inquiry-based method underlies teaching with GIS. "Science teachers approach their subject more as a thing to be investigated through the scientific method. Social studies and geography teachers generally approach their discipline as a body of information to be acquired," claimed Charlie Fitzpatrick, one of the nation's most active trainers of teachers in GIS (Trotter 1998). This implies that science teachers tend to be more constructivist in approach than geography teachers, favoring GIS because it will allow them to *explore* information in the classroom.

Another explanation for the predominance of science teachers' GIS use is that science teachers may be more adequately trained in computer technology than social studies teachers. Despite the fact that many geographers have been leaders in developing and using information technology in schools (Daugherty 1992), many secondary geography teachers are ill-trained in technology.

Structural difficulties imbedded in schools may discourage geography teachers from using GIS. Because science teachers have a longer history of computer use, they are often first to be provided with adequate software and hardware. Social studies teachers are relative latecomers to using computers for more than canned drill or demonstration software. This seems to support Wardley's (1997) study of GIS in education, where 63% of southwestern Michigan *social studies* students did not have access to computers, but the *science* students had better access.

The fact that fewer geography teachers use GIS compared to science teachers has further implications for teaching and learning. Most of the spatial and representational concepts that undergird a GIS have roots in geographyXmap projections, scale, feature representation, coordinate systems, and spatial analysis. If students do not receive the necessary background in the geographic concepts behind GIS, how they learn and what they learn from GIS may be limited.

Teachers were also asked, "If you use GIS, in which subjects do you do so?" In all subjects, the number of subjects where teachers actually using GIS was less than the number of subjects taught, reflecting again the lag between acquiring and using GIS because of implementation challenges. The subjects where teachers use GIS roughly paralleled the subjects mentioned above, with science and geography teachers leading the way. Geography and science teachers (84% and 77%, respectively) are more likely to implement GIS in their classes than history, "other social studies," and math teachers (35%, 49%, and 25%, respectively)(Figure 3.4).

Following science and geography, in order, were “other subjects,” history, “other social studies,” computer science and computer applications, math, and even language arts. An example of a language arts class using GIS is an Advanced Placement (AP) English class where students examine the countries around the world that require English to be taught, to extend what they learned in reading the book entitled *The Mother Tongue* (Bryson 1996). Another teacher responded that she is trying to get GIS taught at Grade 9 for an integrated biology, English, and technology class.

Teachers interested in GIS often need to carve a home for it in the curriculum. Two teachers in North Carolina fit GIS easily into a “Satellites, Computers, and Mapping” course, while another teacher, confronted with the fact that the school had no “GIS” class or program, folded GIS into an urban environmental program. Some teachers find it easier to incorporate GIS as a skills class (teaching *about* GIS instead of teaching *with* GIS) or as a special “club” meeting before or after regular school hours. GIS faces stiff competition in the curriculum, particularly with heightened awareness of national and local standards, allowing few openings for GIS. This represents a significant challenge to its implementation.

The wide spectrum of subjects mentioned leads to two conclusions. First, both the interest in GIS and its actual use measures up to its interdisciplinary claim. Second, GIS is being incorporated within the traditional secondary educational curriculum. Only 11.4% of the respondents indicated that they are using GIS in nontraditional classes such as technology education or agriculture.

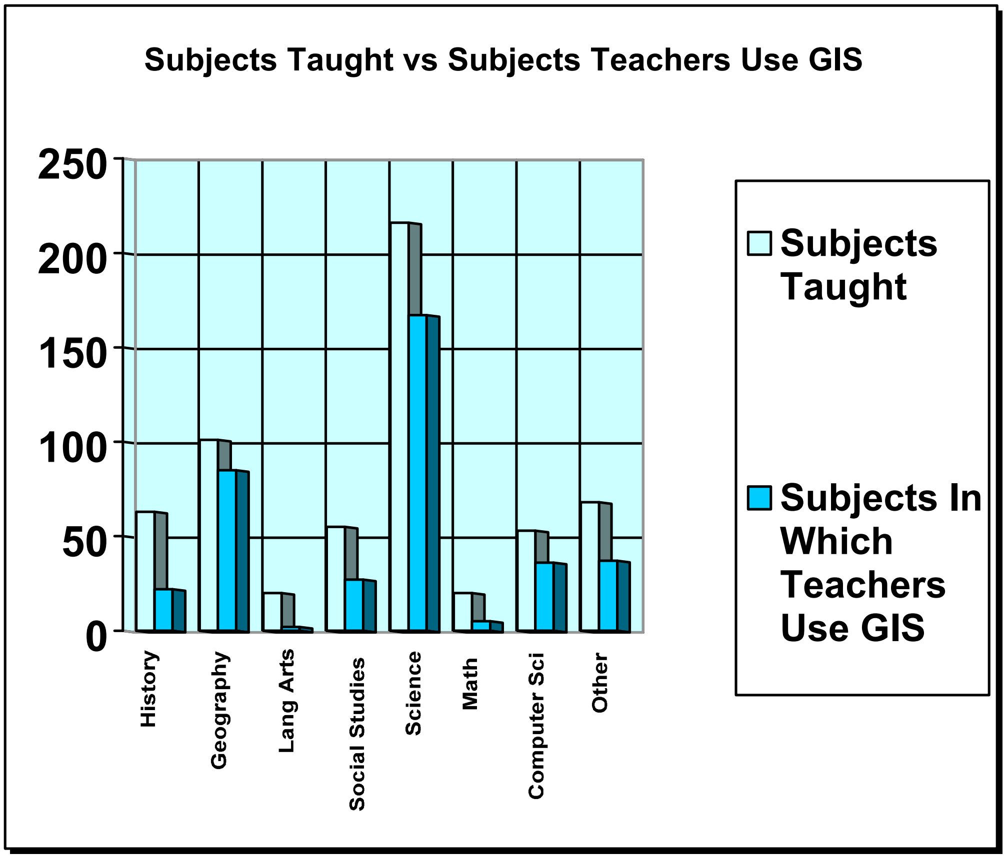

Figure 3.4. Subjects Taught and Subjects in Which Teachers Use GIS.

At the secondary level, teaching *about* GIS is much less common than teaching *with* GIS. A specific “GIS” course was mentioned by only six teachers. This is the direct opposite of the emphasis in the college curriculum, where GIS has been almost exclusively confined to *GIS courses* in which students are learning *about* the software—acquiring technical skills to master the tool. Teaching *with* GIS has led to reformist means of teaching, as indicated by survey respondents. At the same time, teaching *with* GIS acts as a hindrance for its widespread adoption in schools. If teaching *about* GIS were more widespread, it would become known as a tool by more teachers and students, like other ubiquitous computer tools such as word processors, graphics programs, web browsers, and spreadsheets.

Instruction based on geographic information systems is spread throughout all grade levels, with a slight preponderance toward grades 11 and 12 (340) over Grades 9 and 10 (238). This further indicates that educators perceive GIS to be an advanced tool to be used in the upper grades. Geography teachers favor Grades 9 and 10 while science teachers favor grades 11 and 12. This most likely reflects the fact that geography is most often taught in Grades 9 and 10. No difference could be found between the types of lessons described for Grade 9 and Grade 10 versus those described for juniors and seniors. In all cases, lessons cited were usually aligned with reformist, constructivist methods, and will be described more fully in a later section of this chapter.

Technology Access, Characteristics, and Support

Number of and Access to Computers

Student-to-computer data indicate that despite the fact that schools invested over $5 billion annually in computer technology by 1997 (White 1997), students in the schools surveyed generally have poor access to computers. In 21% of classes, the ratio was more than 15 students for each computer. In nearly half (42.8%) of classes, the ratio was equal to or greater than 10 students per computer. At the other end of the continuum, in about one-third (32.8%) of classes was the ratio more favorable to computer use, with less than three students per computer. A chi-square test did not find significant difference in the ratio of students to computers between the adopters and nonadopters (Chi-square value = 10.4117; P=0.064). These results imply that, nationally, most teachers will have difficulty incorporating a computer-based tool such as GIS. As other survey results showed, GIS tends to require more time than other computer software, from teachers and students alike. This means it is even more likely that insufficient computer hardware affects implementation of GIS more than it affects other software. Items that businesses take for granted, such as a telephone near each computer and a computer services section, simply do not exist in most schools.

Teachers run GIS software more commonly on computers in their own classroom (46.3%) than in a shared computer laboratory (27.1%). Because GIS software is memory-intensive and space-intensive, and ideally forms part of a system of peripheral hardware devices such as scanners, global positioning system receivers, printers, and plotters, the relative lack of running GIS in a computer lab may hinder its use. Indeed, the average number of computers in respondents' classrooms is less than five. By contrast, the average number of computers in the shared labs is nearly 22. Computers in an individual teacher's classroom are less likely to be as well supported by the technical staff, be as frequently upgraded, or be as well connected to other devices.

Many respondents indicated that although their school has several large computer labs, it is difficult to schedule lab time for their students. Many teachers run computer laboratory exercises from their own classrooms, where they at least have more control in loading software and managing the systems, as well as allowing better access throughout the day.

Operating System

Most teachers (70.3%) run GIS software on Windows operating systems (95, 98, and NT), rather than Macintosh (26.6%) or Unix (.5%)(n=394). Schools were almost exclusively the domain of Macintosh-based computers during the 1980s. The share of PCs grew throughout the 1990s partly due to a desire to have students use the same systems in common use by business professionals, and partly due to growth in functionality. Unix-based computers were never a viable option for most secondary schools, and were only used by two survey respondents. Despite this growth, over half of computers in secondary schools are still Macintosh-based.

A chi-square test on the operating system indicates a significant difference between adopters versus nonadopters (Chi-square = 23.47; P = 0.000)(Table 3.6):

Table 3.6. Computer Operating System for GIS Adopters vs. Nonadopters, Chi-square Test.

Operating System	Do Not Use GIS	Use GIS	Total
Mac	41 33.06%	24 12.24%	65 20.31%
Windows 95/98	73 58.87%	137 69.90%	210 65.62%
Windows NT	9 7.26%	34 17.35%	43 13.44%
Unix	1 0.81%	1 0.51%	2 0.62%
Total	124 100.00%	196 100.00%	320 100.00%
Pearson chi-square χ^2 (6) = 23.4742 P = 0.000			

Only 12% of teachers using GIS did so on Macintosh systems, but 33% of teachers owning but not using GIS were Macintosh-based. Windows (95, 98, and NT) accounted for over 87% of adopters but only 67% of nonadopters. The predominance of Windows-based PCs as the recommended GIS platform imposes a challenge for Macintosh-based teachers who want to implement GIS. GIS software was developed for industry on mainframe and minicomputers running Unix and Vax operating systems, and during the 1990s was ported largely to desktop PCs, rather than to Macintosh computers. Of the three software packages included in the original population (*MapInfo, Idrisi, and ArcView)*, only *ArcView* is available for the Macintosh platform. However, ESRI has not developed *ArcView* for the Macintosh beyond version 3.0, which dates from late 1997, and has no plans to do so. PC users, on the other hand, had the option of using additional functionality by upgrading to version 3.1 by late 1998, version 3.2 by fall 1999, and version 4.0 planned for 2000. Macintosh users are at a serious disadvantage to PC users when it comes to GIS software. Most teachers are trained on Macintosh systems, and would be required to learn a new operating system in addition to unfamiliar software if they implemented GIS, because it would likely be on PCs. Only those who opted for the older version of *ArcView* or other software could run it on the Macintosh, and ArcView 3.0 will become less desirable over time as new capabilities are developed with the PC version.

Technical Support

Although most surveyed schools (74.2%; n=353) have technical support staff, many teachers expressed frustration both about the lack of and the poor quality of technical assistance in their school. On the question "Does your school have a computer technical support staffperson(s)?," teachers wrote comments such as "We have one who gets paid, but I never see him," and "Yes, but he is an idiot!" Respondents indicated that the technical support staffpersons were either unaware of GIS (27.9%; n=298) or were not supportive of GIS (29.9%), which simply put, spells trouble for successful implementation. Scoring 1 for the "unaware" category, 2 for "no support," 3 for "little support," 4 for "some support," and 5 for "much support," the mean score for this question was 2.51. This mean, midway between "no support" and "little support," suggests one key reason why GIS is typically not implemented by multiple teachers within a school. Technical support spreads the awareness of and access to a computer technology throughout a school. GIS requires ongoing technical assistance for such tasks as sharing files over a network, downloading data from CD-ROMs and from the Internet, reformatting data, scanning, plotting, and troubleshooting. If technical support staff is not brought on board as full participants in the project, teachers will be faced with the prospect of performing systems administration duties on top of their already busy schedules. Indeed, this situation is rareX12.5% of respondents both teach and serve as technical support staffperson. This indicates the dedication of these individuals to implement GIS technology. On the other hand, teachers who are also technical support staff may find it easier to implement GIS, since they exercise more control over both the software that can be loaded and who has access to it. They also may be more predisposed to using GIS in the first place, because they already possess a greater degree of technical skills than most teachers have.

Does increased technical support raise the amount of GIS implementation in a school? Over one-quarter (26.8%) of teachers reported that they received “some” or “much” support from their technical staff on GIS. GIS seems to flourish in a few schools where technology is emphasized, such as in one school where the principal stated that “We believe that every teacher needs to be a technology teacher.” A chi-square test found that the amount of technical support is significantly higher for GIS-adopting teachers than for those who do not use GIS, although the amount of support for both groups is low (chi-square value 19.84; P=0.001)(Table 3.7):

Table 3.7. Amount of Technical Support for GIS Adopters vs. Nonadopters, Chi-square test.

Amount of Technical Support	Do Not Use GIS	Use GIS	Total
Technical Support Staff Not Aware of GIS	46 38.33%	36 21.30%	82 28.37%
None	36 30.00%	49 28.99%	85 29.41%
Little	20 16.67%	25 14.79%	45 15.57%
Some	14 11.67%	33 19.53%	47 16.26%
Much	4 3.33%	26 15.38%	30 10.38%
Total	120 100.00%	169 100.00%	289 100.00%
Pearson chi-square χ^2 (6) = 19.8399 P = 0.001			

Administrative Support

Overall administrative support was slightly more evident than technical support, but using the same scoring guide as for technical support, the mean for administrative support was still a low 2.80. This means that the average teacher receives even less than "little" support from the administration, such as principals, the school board, and the school district superintendent. Nearly half (45.5%; n=345) of teachers receive no administrative support, either because the administration was unaware of GIS or simply did not show an interest in it. Like the lack of technical support, little administrative support spells trouble for widespread GIS implementation in secondary schools. By its nature, GIS is a community-based technology, which is enhanced by a network of technical support, administrative support, and connection with data providers and users in the community. A chi-square test found that the amount of administrative support is significantly higher for GIS-adopting teachers than nonadopters (chi-square value 25.06; P=0.000). The amount of administrative support for adopters is higher than the amount of technical support they receive, which confirms data that despite support, adopters are largely on their own technically.

One teacher, in describing a successful GIS project, wrote of the importance of administrative support:

> "Our principals were proud and excited in leading the school in a direction that was new and untested. The first problem is that most principals want to stay on traveled ground, and not into unchartered [sic] territory. The second problem is that students are not afraid of technology but rather enjoy the challenge, while some teachers run from computers."

The school district provides one link between the school and the community. If this link is not strong, the teacher will find it difficult to break out of the "trailblazer" mode, but be forced to "go it alone." Innovation research suggests that "change agents"—in this case, teachers using GIS—must concentrate their energies on the opinion leaders in the social system to enhance the possibility of adopting innovations. The lack of administrative support will therefore continue to make the pace of GIS implementation sluggish.

Implementation of GIS: Spatial Analysis

The spatial distribution of teachers receiving their GIS training and the population of secondary schoolteachers owning GIS software are related, and display a regionally-clustered pattern (Figure 3.5). Both are concentrated near the locations of past science and geography education conferences, educational inservice locations (which often are held on university campuses), and offices of GIS software vendors (Figure 3.5). Just 11 states accounted for over 59% (n=302) of the locations where teachers received their training, including California (41 responses), Minnesota (20), Texas and New Jersey (16 each), Massachusetts (15), New York and Colorado

(14 each), Montana (13), North Carolina (12), and Connecticut and Wyoming (9 each). Especially evident are the frequency of responses listing San Francisco, Stockton, and Redlands, California; Minneapolis, Minnesota; Storrs, Connecticut; and Mahwah, New Jersey. ESRI's influence can be detected in the frequency of respondents listing Redlands, California (ESRI's headquarters), San Diego and Palm Springs, California (locations of ESRI's conferences), and Minneapolis, Minnesota (the headquarters of ESRI's schools and libraries program). The cluster of Colorado training responses can be largely explained by the Geological Society of America's Earth and Space Science Technological Education Project (ESSTEP). Funded by the National Science Foundation, ESSTEP sponsored two-week institutes over three successive summers from 1997 through 1999. ESSTEP's model joined teams of primary, secondary, and college-level educators from the same geographic area to learn about multimedia, Internet, GPS, GIS, and remote sensing. One goal was for these cross-curricular teams to continue to work together in their community after the ESSTEP training had ended. GIS institutes at The University of Connecticut and Clark University, and training conducted by TERC, ESRI's Boston office, and the Boshe Institute are partly responsible for two New England clusters. Four summers of GIS institutes by North Carolina State University have created a cluster focused on Raleigh. The *MapInfo* Corporation has been active in Illinois. The Montana cluster can be partly explained by the Upper Midwest Aerospace Consortium (UMAC), which also caused some of the responses in UMAC's other states: North Dakota, South Dakota, Wyoming, and Idaho. The effect of the GeoTech conference in Dallas, which has focused on geographic technology annually since 1988, and two national GIS institutes in San Marcos, Texas, is also evident.

The pattern of survey respondents as well as the total population of secondary teachers using GIS reflects diffusion from the location where teachers were first trained[1]. This diffusion is largely confined to the states or regions where the initial training took place (Figure 3.5). The same 11 states accounted for over 45% (n=409) of all respondents, with New York, California, and New Jersey accounting for 18.6% of all responses. The pattern of GIS implementation (Figure 3.6) shows a mix of users (any teacher who at least demonstrates GIS on a computer) and non-users in each state. Again, the pattern is clustered, centered on the locations of the original training sessions. Survey responses showed that seven states (Alabama, Georgia, South Carolina, Louisiana, New Mexico, Arkansas, and Missouri) are severely underrepresented in terms of teachers using GIS software—two or less responses were received from each of these states, and no teachers indicated that they were trained there.

Method and Amount of GIS Training

Teachers indicated that they were trained in GIS in a wide variety of ways. This reflects the lack of a national curriculum or coordinated effort to support the implementation of this technology. Because of this lack of coordination, teachers act largely on their own to seek training. The fact that nearly 17% (n=395) indicated that they trained themselves confirms the suspicion that these teachers are "trailblazers"Xearly adopters of technology diffusion who act on their own, taking the risks of spending time and effort with something new—because of a perceived benefit. This is particularly notable concerning a complex software package such as

[1] Showing the pattern of the population of secondary teachers owning GIS software is precluded by an agreement with the three vendors providing the mailing list.

a GIS, the effectiveness of which has not been extensively tested, and a tool for which few lessons exist.

The market for GIS training is at least one-third of the $5 billion annual expenditures on GIS (Phoenix 1999), reflecting the difficulty of learning the software and the need for ongoing support. Unlike GIS users in the petroleum and natural resources sectors, few training sessions are geared toward the educational community. Although many GIS user groups have held annual meetings since the mid-1980s, it wasn't until 2000 that a national educational user conference was conducted. Nearly one-fourth (23.7%; n=367) of respondents indicated that they have not spent any time in formal training classes, and nearly two-thirds (64.6%) have had less than 20 hours of training (Figure 3.7). Only 10.1% of respondents have had over 80 hours of training. Teachers with higher amounts of training tended to be those who are developing modules, gathering data, and using GIS in multiple lessons. They are, in effect, resolving many of the implementation issues, which paves the way for additional teachers to follow—the "early majority" in diffusion literature. The lack of coordinated training is a significant hindrance to GIS adoption by high school teachers. Survey respondents repeatedly mentioned that general GIS training does not address the implementation in the daily curriculum that teachers require to "make it work." Furthermore, general training emphasizes the teaching *about* GIS model, a model which the survey found to be rare compared to teaching *with* GIS. GIS appears to be more than a technology—it involves a specific teaching *method* that is unfamiliar to most teachers.

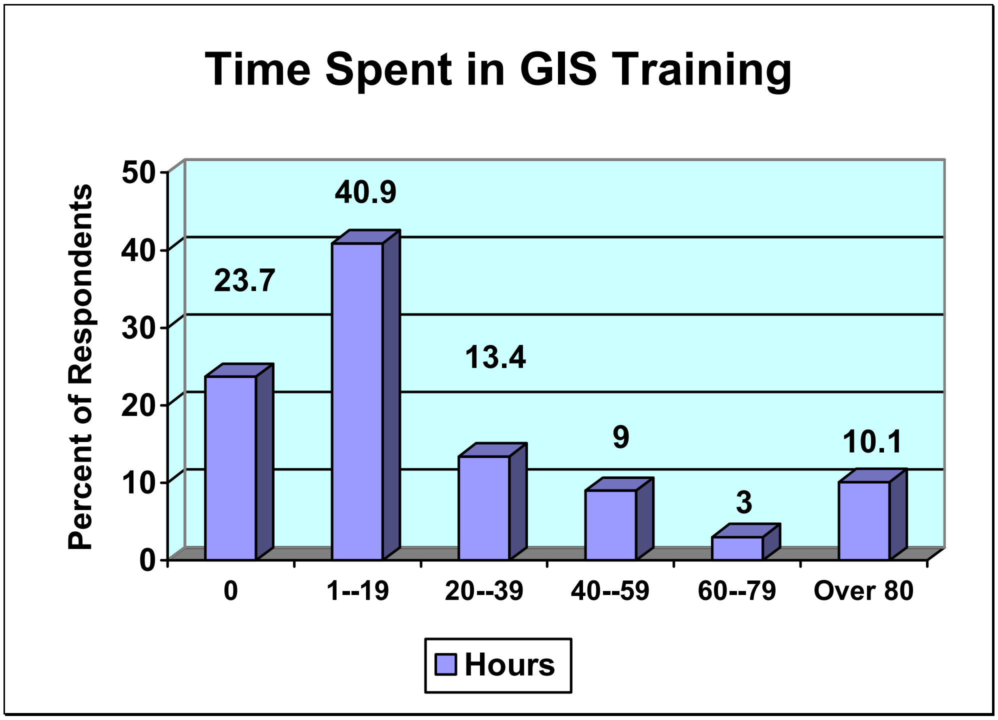

Figure 3.7. Time Spent in GIS Training.

The fact that only 35.5% of respondents have taken over 20 hours of GIS training compares well with a U.S. Department of Education survey showing that only 15% of the nation's teachers had at least nine hours of instruction in educational technology (Zehr 1997). However, even teachers with a background in GIS said that they require <u>more</u> training for GIS to have a significant impact on their teaching.

Teachers, like other GIS user groups, need hands-on training sessions specifically geared toward their needs. For educators, this means inservice training, and indeed, inservices provided the most frequent training (30.1%). Access to good equipment and facilities has improved, but teacher professional development remains a serious barrier. There are few incentives and teachers have little time to integrate new technologies. Teachers need personal experience for technology to be implemented, especially with software with a long-term learning curve such as

GIS. Because of the complexity of the tool, teachers have difficulty finding time to train their fellow teachers (3%), which slows implementation. One exception is the Fairfax County, Virginia, school district, where GIS has diffused throughout the district's 24 high schools, largely as a result of the efforts of a single teacher.

Bednarz and Audet (1999) went so far as to state that "until consensus is reached that GIS has a role in preservice education, then we will continue to see a directionless patchwork of [teacher training] programs" (p. 66). One recommended solution is for university-level geographers to use GIS in their courses, and thereby model teaching with the tool to students who will later become inservice teachers.

Few teachers are able to learn about GIS on the Internet (1%), again reflecting the tool's complexity. It is not something easily learned with a few tutorials on the World Wide Web. Geographic alliance-sponsored training was cited only 9.4% of the time, which reflects the predominance of science teachers as GIS users over geography teachers.

Because of the ubiquity of GIS at the college level, particularly in geography, 17 respondents (4.3%) indicated that they became interested in GIS through a college-level course. As GIS diffuses from geography to geology, emergency management, biology, ecology, and particularly to business marketing and management, its influence on future secondary teachers will increase. Because of the diffusion of GIS in the workplace, acquaintances and family members sometimes spark a teacher's interest to seek a training class. A respondent from Houston, Texas, for example, became interested in the tool through a spouse who worked as a GIS specialist for Texaco.

Because of the lack of a coordinated effort and a national GIS curriculum, and because of the specialized nature of the software and associated data, much GIS use in education results from efforts by GIS software companies (12.2%). The most frequent commercial GIS vendors in education mentioned were *MapInfo*, *Idrisi*, and ESRI. Because *Idrisi* was written by Clark Labs at the Department of Geography at Clark University, it is not a private company in the same sense as the others, but it does receive revenue through its GIS software and its goals are similar to that of a commercial vendor. Each vendor has promoted GIS in education through sponsoring exhibits and workshops at conferences such as that of the National Science Teachers Association, the National Education and Computing Conference, and the National Council for Geographic Education. GIS is too complex to fully train a user in a demonstration or workshop at these conferences, but these activities do generate interest and demand for additional training among educators. These same companies have also been active in long-term training, sponsoring workshops in conjunction with these conferences and also sponsoring training events not associated with a conference.

ESRI, in particular, has been active in training educators at all levels. Based on survey responses, the ESRI schools and libraries team has had more influence on GIS implementation in education than any other GIS vendor. Repeated mention of the ESRI team of Charlie Fitzpatrick, George Dailey, and Angela Lee reflect the fact that this team has conducted over 100 workshops, demonstrations, and exhibits annually since 1992. Largely through their efforts, *ArcView* has become the most widely used GIS software in education. The ESRI Adopt-A-School program, which began in 1992, combines the resources of GIS professionals in the community with the schools in that community (ESRI 1998c). GIS professionals have provided training, data, hardware, software, and projects to the schools. Local data and community support are the keys to its success.

Several respondents mentioned training at the first GIS summer institute, sponsored by the National Council for Geographic Education and the Geographic

Education National Implementation Project, and supported by ESRI and the USGS. This institute brought together 32 teachers for two weeks during July 1998, at Southwest Texas State University, San Marcos, Texas.

The Upper Midwest Aerospace Consortium (UMAC), the Earth and Space Science Technological Education Project (ESSTEP), and the Center for Image Processing in Education (CIPE) were often mentioned. Based in Tucson, Arizona, CIPE uses imaging software originally developed for medical research at the National Institute of Health (NIH) called *NIH Image*. The Technological Educational Research Center (TERC) in Cambridge, Massachusetts has sponsored several conferences on educational GIS, conducts research, and develops spatial analysis CD-ROMs such as *Virtual Oceans*. The Kansas Collaborative Research Network (KanCRN) is an Internet-based community of researchers, teachers, and students interested in collaborative scientific research, and is an example of a growing number of state-based organizations conducting technology training. A number of teachers reported being trained through the $800,000 NSF-funded "GIS Access" project. College-level geography faculty conducted the training, which will serve 120 secondary and university educators when complete in 2000 (GIS Access 1999). The Berkeley Geographic Research Group has been training educators through its GEODESY project and beginning in 1999 throughout Mississippi school districts.

Other respondents listed GLOBE workshops as the means by which they were trained. The GLOBE program (Global Learning and Observations to Benefit the Environment) was announced by Vice President Gore on Earth Day 1994, and has since grown to 8,500 schools (McGarigle 1999b). Teachers and students from around the world monitor the environment—from temperature and precipitation to soil moisture and water chemistry (Murphy and Coppola 1997). The information is gathered and posted on NOAA and NASA Internet sites for everyone to analyze, including scientists, who use the information to fill in gaps between satellite data (Weiss 1996). ESRI and Intergraph have each donated over 7,000 CD-ROMs containing data and GIS software to GLOBE franchises (Environmental Systems Research Institute 1999a). The large numbers of schools participating in GLOBE make this program a key means of GIS diffusion in the schools.

Based on survey responses, I recommend that another group should be considered as an influential force in the spread of GIS in education—the teachers responding to the survey who are “high implementers” of the technology. Adoption of a new technology often depends on trailblazers, or change agents, who are required to be charismatic individuals (Kanter 1983), zealous to make others aware and competent in the innovation. These teachers do not give up, despite facing obstacles in implementation. For example, even after one of these teachers’ schools took most of her computers away—computers that she wrote a GIS grant to obtain—she went on to become one of the preeminent GIS educators in the nation.

Some of these teachers, who have participated in over 80 hours of GIS training, are repeatedly mentioned in conference programs, which shows that they, unlike the bulk of the survey respondents, frequently train other teachers in GIS. Many of these teachers have become Authorized Training Program (ATP) instructors for ESRI. The ATP program allows non-ESRI staff to conduct training as independent businesspersons using the ESRI name. The expansion of the program in 1999 to include educators means that these teachers can operate GIS consulting businesses on the side, influencing a far greater number of educators than the GIS vendors alone can influence.

Implementation of GIS: Temporal Analysis and Extent in the Curriculum

Two questions were asked concerning the dates surrounding GIS in the curriculum. Teachers were asked when they first obtained GIS software, and when they first began using GIS (Figure 3.8).

The survey revealed that GIS is both a recent and a growing phenomenon in secondary education. Only five teachers indicated they were using the tool in 1990. However, over 35% (138; n=384) indicated that they began using it during the 1997-1998 school year. The rate of GIS implementation rose 43% during 1995-1996 over the previous period. During 1997-1998, the rate of GIS implementation rose 155% over the previous period, nearly tripling the number of teachers using GIS from 54 to 138.

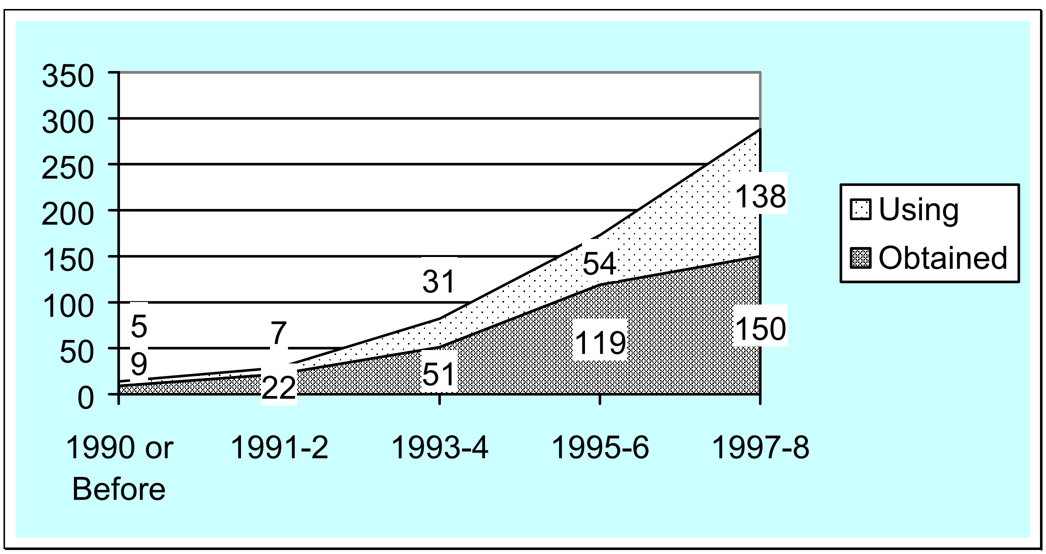

Figure 3.8. Date of Obtaining and Using GIS.

Despite this growth rate in GIS implementation in education, the survey revealed several patterns that signify restraints on its expansion. Measuring the time between the date that the software was obtained and the date that the teachers began using it in the curriculum indicates that implementation challenges exist. In less than half of the cases (44.4%; n=351) did the teacher *obtain* and *begin using* GIS in the same academic year. In 35.9% of cases, a one-to-two year delay occurred, and in nearly one out of every five schools (19.7%), at least three years' delay took place. In 17 schools, the delay was *over five years.*

One teacher's response exemplified a key reason for the delay:

> "My primary obstacle was the fact I had no local GIS professional and no local data to work with. For the next two years I did more playing than work with the program. I used views I created to help aid my lectures and I was able to start a small GIS club after school."

It was not until the teacher began networking with the local community did GIS become a part of the curriculum: The teacher found the regional planning office that used GIS. The teacher converted the planning data and assigned three Grade 9 students to work on planning a bicycle path.

Even more telling of the challenges teachers encounter when implementing GIS is that nearly half of all responding teachers (45.1%; n=370) *are still not using GIS in the curriculum* (Figure 3.9). These include teachers who indicated that they are "not yet" using GIS or that they "plan to" use GIS in the future (Figure 3.10). Considering that the survey is biased toward GIS adopters than nonadopters, it is likely that less than half of the total population of secondary teachers owning GIS software are actually using it. Verifying internal validity by checking responses to other questions confirms these figures. Out of 409 questionnaires tabulated, only 41.8% of teachers indicated that they use GIS in Grade 12. All other grades were listed less frequently. All other categories of GIS training were indicated with 29% or less frequency. Science was the most frequent subject in which teachers used GIS, but only by 167 respondents (40.8%). When asked how many teachers use GIS at the school, 27.9% indicated that *no teachers* were using it.

Thus, many teachers have powerful software in their hands—software that has largely, until recently, been confined to those in government and business. Nearly one out of two boxes of this software sits on the shelf, unused. The reasons why will be explored later in this chapter. Survey results support an estimate by education professor Becker (Viadero 1997a: 16) that only 5% of computer-using teachers have students use computers as a tool to solve problems or create a product, rather than as a reward for completing other work or to master skills.

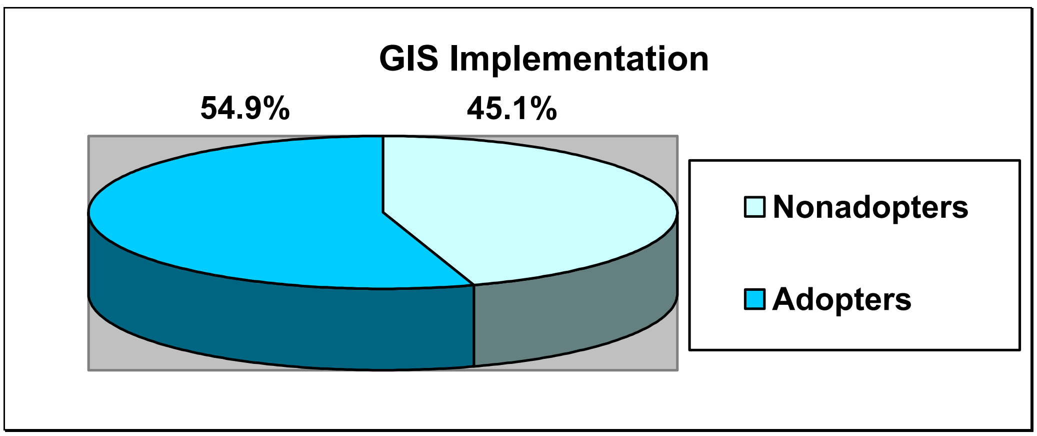

Figure 3.9. GIS Implementation: Adopters vs. Nonadopters.

In contrast to this low percentage of teachers using GIS, over 85% of the teachers who attended the first national GIS institute in San Marcos, Texas had implemented GIS in the following year. The difference was because of the establishment of a listserve specifically for the participants that served as continual technical support and personal encouragement, the availability of post-institute training opportunities (Bednarz 1999), the requirement that each teacher develop two peer-reviewed lessons, and the free provision of GIS software and a large volume of spatial data free to the teachers.

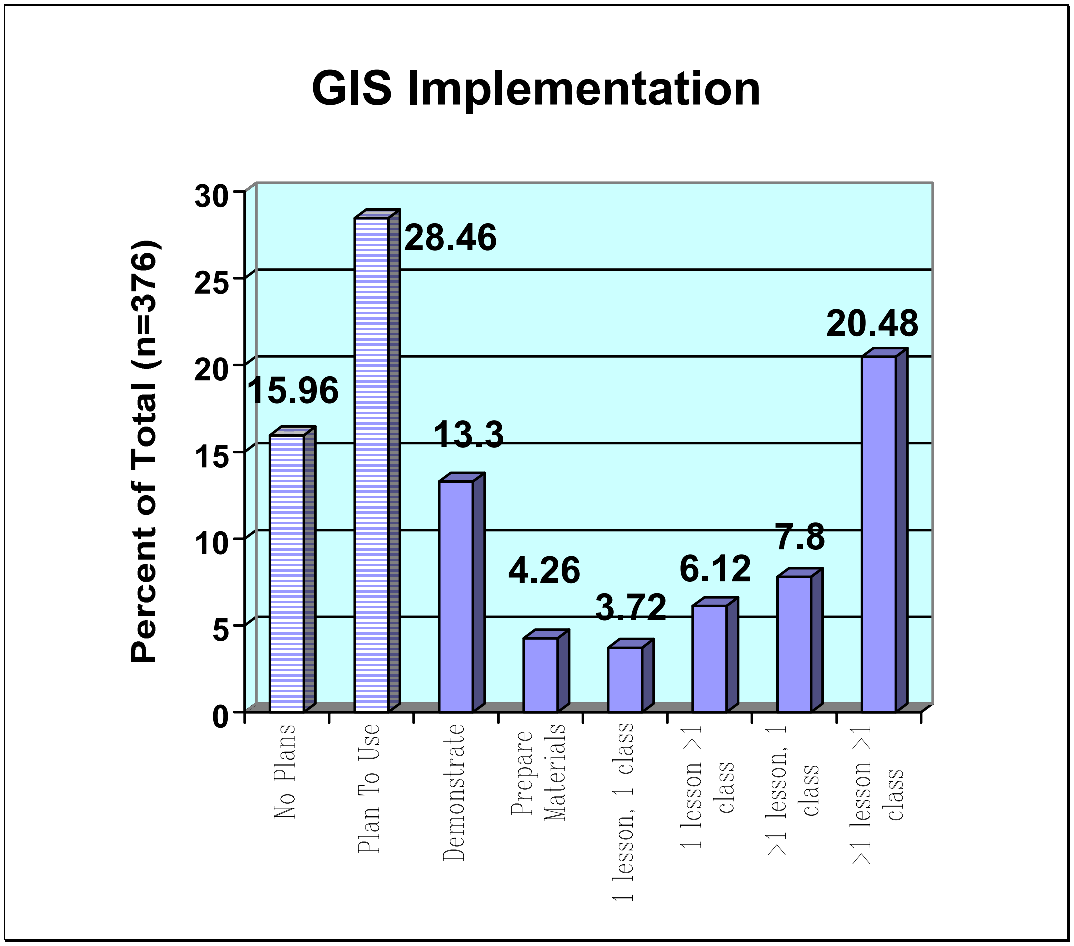

Figure 3.10. Extent of GIS Implementation in the Curriculum.

However, many teachers responding to the survey (55.7%) *are* using GIS in the curriculum, exhibiting a wide variety of settings, to different degrees, and in many ways. Essential in an implementation and diffusion analysis is a consideration of both *how* a technology is adopted and the *amount* of use. Some are using GIS in powerful ways, which will be explored later in this chapter. Here, the *amount* of GIS implementation can be illustrated by the categories in Table 3.1 (page 90), with the highest amount of GIS implementation at the bottom of the table.

Survey responses considered the *highest* degree of implementation for each respondent. However, teachers often use GIS simultaneously along many points of the continuum. Teachers may implement GIS-based lessons in one class, and might use the software to create materials for a traditional lesson in another class. On the high end of the implementation continuum, 20.48% of the total respondents use it in more than one lesson in more than one class (Figure 3.10).

Even among this group, many approaches are practiced. Students might not use GIS software or even use the computer more than a small fraction of the semester. One teacher in the high-implementation category wrote that her students work on the computer only 20 days per year. Lessons may be step-by-step in a very concrete, sequential manner, or they may be quite informal, allowing the students the bulk of the class period to determine an answer after a short introduction by the teacher. Furthermore, teachers using GIS have not abandoned other instructional media and lessons. They seem to recognize that while GIS is an excellent tool, it is not meant to replace every lesson and medium in their curriculum.

The lessons described by this small but influential group of teachers who implement GIS in many lessons and classes exhibit classroom practices that adhere to the reform vision of education. These lessons will be described later in this chapter. GIS adopters are small in number partly because they are forced to develop their own materials. As the literature review revealed, there are few GIS-based lessons. This situation obliges teachers to act on their own to create these lessons. In so doing, they display a high degree of creativity. However, this situation perpetuates the "lone trailblazer" culture of the teacher using GIS, and discourages many teachers from adopting it.

Between the nonadopters and high implementers lie teachers who demonstrate GIS to the class in a lecture-type setting (9.5%), using a non-traditional tool in a traditional way. Although they have "adopted" the technology, they are not using it in the way it was designed. It is a big step from *demonstrating* GIS to *using*

GIS—one is passive, the other, active. Audet and Paris (1997: 300) make a distinction between “knowing how to operate a GIS and knowing how and when to apply GIS to solve problems.” Still, for many teachers, the demonstration stage represents the stepping-stone to full implementation as they grow in their comfort level of working with the software. Next on the continuum are teachers who use GIS to produce curricular materials, such as charts and maps. GIS allows a teacher to produce quick maps at an infinite variety of scales, with tailored content such as climate, transportation, or national boundaries, to suit a particular lesson.

Implementing GIS technology represents, in the words of one respondent, a “big change in the way you teach. The things you see going on in these classrooms now are not anything like traditional science courses.” It requires a teacher to accept the fact that they are teaching something they have not personally mastered, accept more instability and unknowns, be willing to let students take the lead in certain aspects of their learning, and be willing to allow some open-endedness in each lesson. In isolated but growing incidents, GIS technology is forcing the traditional courses to change and new courses to be added. “Geosystems” is one such new type of course, combining geology, geography, statistics, biology, chemistry, computer science, and remote sensing. This course in Fairfax County School District, Virginia, emphasizes collecting data, the investigative process, and real life problems in a technology-rich environment.

Another method of evaluating the degree of implementation of a phenomenon within a school is to measure the number of teachers and students that are involved with the phenomenon. The survey asked how many teachers, including themselves, were using GIS in the school. The most common answer was that *one* teacher used GIS in the school (141; 39.7%; n=355), further supporting the above argument that GIS-using teachers are, by and large, implementing the technology by themselves in a school. The second-most common answer given (32.1%) was that *no* teachers were using the technology. This supports the above discovery that GIS, even in schools who have been given or purchased software, is more commonly on the shelf rather than on the computer. In one-quarter of schools (24.9%), more than one teacher is using GIS. Of the teachers *using* GIS, nearly half (48.2%) mentioned that only one teacher was using it in the school, including themselves, and 20.5% indicated that two teachers were using it.

A chi-square test found a significant difference in the distribution of the number of teachers using GIS in a school and the degree of GIS implementation use (Table 3.8). The single teacher in a school predominates at all levels of GIS use. The presence of more than one teacher using GIS in a school appears to encourage a higher implementation rate. Likely reasons are the practicality of having more than one teacher developing lessons and obtaining spatial data, and from the mutual technical and emotional support among teachers—he or she is not alone.

An examination of the original listings from the three software vendors confirms these findings. Less than 15 of over 1,800 schools on the list were included on more than one list. Requests for GIS software are not coming from multiple teachers within a school, but typically from one teacher who is intrigued enough to explore its use.

Table 3.8. Degree of GIS Use vs. the Number of Teachers Using GIS at Each School, Chi-square test.

	Number of Teachers Using GIS at Each School					
Degree of GIS Use	**None**	**1**	**2**	**3**	**> 3**	**Total**
None	36 32.43%	6 4.29%	0 0.00%	0 0.00%	0 0.00%	42 12.39%
Plan To Use	48 43.24%	38 27.14%	10 19.61%	3 16.67%	3 15.79%	102 30.09%
Demonstrate GIS in Classroom	10 9.01%	23 16.43%	5 9.80%	3 16.67%	1 5.26%	42 12.39%
Create Curricular Materials with GIS	2 1.80%	5 3.57%	4 7.84%	0 0.00%	3 15.79%	14 4.13%
Use in 1 lesson in 1 class	4 3.60%	8 5.71%	1 1.96%	0 0.00%	1 5.26%	14 4.13%
Use in 1 lesson in more than one class	2 1.80%	13 9.29%	4 7.84%	1 5.56%	1 5.26%	21 6.19%
Use in more than 1 lesson in 1 class	2 1.80%	15 10.71%	6 11.76%	5 27.78%	1 5.26%	29 8.55%
Use in more than 1 lesson in more than 1 class	7 6.31%	32 22.86%	21 41.18%	6 33.33%	9 47.37%	75 22.12%
Total	111 100.0%	140 100.0%	51 100.0%	18 100.0%	19 100.0%	339 100.0%
Pearson chi-square χ^2 (28) = 130.7324 P = 0.000						

GIS is not used by a large percentage of the student body within each school. This supports the discovery that a single teacher usually spearheads GIS implementation. Although teachers commented on the interdisciplinary nature of GIS, to a large extent they are still in the process of convincing other teachers in the school to use it. In 42.6% of schools, only one-tenth of the student body uses the technology, and in 29.4% of schools, none of the students are exposed to GIS. In only 1.7% of schools surveyed (6 schools) do *all* students have the opportunity to use it. Therefore, in most schools (72%), no more than one out of every 10 students is aware of GIS.

GIS-Based Lessons

Teachers were asked to briefly describe one lesson in which they use GIS. Analyzing these descriptions illustrates the appeal, versatility, and applicability of GIS in education. Examples included a chemical analysis of volcanic lava, investigating an arboretum that was damaged by a local golf course, analyzing deforestation versus economics in Africa from 1980-1985, examining snow depth per storm related to elevation, analyzing salmon spawning habitat, tracking pH values and pollutants in streams, assessing Yellowstone earthquake risk, analyzing radio-telemetry data to determine black bear habitat, and mapping auto thefts in the community.

One teacher gave students a role-playing task as members of a White House travel bureau. Students selected six indicators that would indicate the level of stress in Africa. After identifying countries that have the highest level of each stress, students chose locations around the continent for the President to visit.

One class used remotely-sensed multispectral imagery from SPOT and NASA satellites to create a GIS vegetation base map for the county and for ongoing environmental studies over time. Students compared archival and current data to assess the adequacy of surface drainage systems to handle runoff during and immediately after precipitation events. They analyzed deforestation patterns, air quality data, urbanization, and tracked point source pollution. Data were made available using the Internet. The high school teamed up with the community improvement district to study the best management practices for the local watershed. Students collected soils samples to produce a soil phosphorous outline map and assess ground water quality.

Several characteristics were common to these lessons. First, teachers using GIS were also comfortable with other technology, such as remote sensing, global positioning systems, presentation and multimedia software, the Internet, and in a few cases, specialized software such CAMEO, used to clean up hazardous materials by emergency crews. Second, the predominance of chemistry, hydrology, and biology lessons was evident, reflecting the fact that science teachers use GIS more than geography teachers. Teachers most often used GIS to analyze watersheds and the chemical characteristics of rivers (49 mentioned).

Many lessons (28 mentioned) emphasized connections to and data from the students' own communities, described by one teacher:

> "GIS gives new meaning to the old saying 'Think globally, act locally.' GIS fosters links between school and community. Through its spatial display of data, GIS provides 'instant gratification' for fieldwork in the community. Students can explore authentic issues (for example, [the] impact of a new road; [the] location of traffic accidents) and make a real contribution to the analysis of community issues."

One high school's Urban Environmental Education program brought 137 high school students and 80 adult students from the community together for evening programs. Another community program began when the hazardous materials Fire Captain asked a GIS class if they would assist the community in collecting information for the local emergency planning committee. They used CAMEO software (Computer-aided Management of Emergency Operations), a mapping program called MARPLOT (Mapping Application for Response and Planning of Local Operational Tasks), and a program to model hazardous atmospheres (ALOHA) to participate with the emergency response crews in a full field hazardous materials simulation. This attracted a grant from Bell Atlantic for the city and seven other communities to expand this curriculum. The high school began conducting summer GIS training programs in 1997.

In some cases, diffusion of GIS was directed from a school to the entire school district, evidenced by school districts adopting GIS for their day-to-day management. The school described above with the urban environmental education program provides GIS services to the community, including demographic studies for small businesses, resource mapping and planning for local units of government, and design of school transportation services. Project accomplishments went beyond the exploration of environmental quality of the urban environment, for it stressed positive role models, career pathways, high schoolers sharing with elementary students, field trips, and conferences. Parliamentary officials from Belarus met with the students and were impressed with the idea of how students can help with the preparation and analysis of information.

Community service is also a thread common to many GIS-based projects, such as a project that analyzed the type of pipe needed to mitigate lead contamination in household drinking water in a city. Selected as best environmental science project in the nation for that year by The Seiko Youth Challenge Year V, each student received $6,250 toward college education.

Teachers felt that they should prepare students to use *information*, rather than preparing them *for the next course*. Connecting with community organizations provides field work for students and data to use in the classroom. One teacher had "wonderful support" from the Utah Geographic Alliance, the Utah State Parks Department, and Utah Automated Geographic Reference Center, resulting in free access to and data about their study site on Antelope Island.

GIS is being used in the curriculum as a *process,* involving the student in open-ended projects with real-world data. One teacher mentioned that the "cement needed in education is the connection to the real world." The authors of the national geography standards also referred to GIS as a process (Geography Education Standards Project 1994: 45). The lessons cited by the teachers are not traditional place-name and location geography instruction, nor are they traditional science experiments. More than a set of computer *tools*, GIS entails a specific *method* of its own for analyzing the world, applying spatial data to solve problems. This method, more than the tools, makes GIS attractive to teachers and administrators. "[For years] we said memorize, memorize, memorize, because the rules would never change. The rules changed" (Environmental Systems Research Institute 1995). Teachers using GIS view themselves as co-learners with their students, as evidenced by one survey respondent:

> "I continually learn something new. My students are using a cutting-edge technology. We learn and explore together in problem-based projects. We all enjoy learning together and seeking new applications of the software."

These teachers perceive that they are teaching in a new way that involves more risk-taking and adopting the role as facilitator: "Nothing works the first time. Don't get frustrated—go with it and learn with your students." "Be amazed at what the students will do that you never in a million years would have thought of." "I feel like I'm jumping into the deep end of a pool. I'm already wet, so I'll stay in."

Since students using GIS gather and analyze real-world data, teachers perceive it as encouraging learning through making connections and analyzing patterns. One respondent remarked "how much better one can understand the world when one can make pictures of it that make sense."

Another characteristic of many of the lessons is that they involve "ill-structured" problems. "Ill-structured" problems reflect those in typical life and workplace situationsΧmore information is needed than is provided; there is no right way or fixed formula to conduct the investigation; each problem is unique; changes may be made in the lesson as additional information is found; and often there is no single right answer (Stepien, Gallagher, and Workman 1993). Learning thus depends on the context, showing that these lessons are constructivist in nature and follow the "problem-solving" approach described in Chapter 2.

GIS-based lessons tend to be interdisciplinary, best illustrated by the response from one teacher:

> "I wanted to incorporate *ArcView* [GIS] into my curriculum because I could see an excellent tool for subject integration. *ArcView* will let me teach geography, math, and language arts together, just like we find it in the real world, and not separated like we find in subject area books. We want students to function in a real world setting but teach curriculum in fragmented subject areas. *ArcView* gives me the opportunity to teach using spatial concepts so students gain a greater awareness of their environment, and the whole *real* picture."

Another study cited a project where students created a video documenting an urban lake they wanted to save. The literature and English teachers were essential in developing the script.

GIS also appears to foster the integration of geography across the curriculum:

> "I feel that technology is the perfect medium to integrate geography across the curriculum. I'd love to see our science teachers embrace its use as well as the whole social studies department. I've really only just begun, but it's been a dream of mine for four years and finally it's materializing."

Many lessons emphasized the inclusion of field work. Rather than disconnecting students from their environment by sitting at a computer, GIS seems to foster at least some connection to the students' surroundings. This was evident in the inclusion of fieldwork such as recording bird nests in a local wetland, but also in gathering data from a variety of community personnel.

Most GIS-based lessons are conducted with commercial off-the-shelf GIS software. Fewer lessons were cited that used customized interfaces such as TERC's "Mapping Our City" and the Berkeley Geographic Research Group's

GEODESY project. This has implications for policy—perhaps funds would be best spent training GIS users in commercial packages.

GIS projects were repeatedly linked to current events. One teacher required students to construct maps of the Mediterranean region focused on Turkey following earthquakes in the region. His assessment indicated that students possessed a significant degree of spatial knowledge of the region, and a conceptual understanding of the relationship between geologic features and geologic events. Most learners were able to extend these principles to include the earthquake that occurred soon afterwards in Greece.

Assessments associated with these lessons are non-traditional, "authentic" assessments, reflecting the types of evaluations done in the workplace. For example, the final exam for a river environmental study was the students' portfolio of data and maps they created over the course of a year. Teachers using GIS with authentic assessments recognize that not every student learns the same thing or in the same way: "They don't all have to have the same level of expertise [upon completion of the unit]." A familiar refrain through the surveys was teachers' desire to develop communication skills as well as analytical skills. If students cannot communicate the results of their research to others, the entire project is judged to be less worthy, despite the soundness of their investigation. Presentations for GIS-based projects were often conducted not only for the student's classroom, but also for the parent-teacher organization, legislators, community leaders, peers, other teachers, and even the news media.

According to survey responses from teachers who use GIS in at least one lesson, the previous analysis shows that these classrooms fit the constructivist model (Table 3.9).

Table 3.9. Model of Social Organization of Classrooms in a Traditional and Constructivist Orientation (from Oblinger and Maruyama 1996).

Traditional Orientation	Constructivist Orientation	Work Requirements
Learn facts	Project-based learning	Problem-solving
Individual effort	Collaborative – cooperative learning	Team skills
Passing a test	Authentic practice	Learning how to learn
Achieving a grade	Performance assessment	Continuous improvement
Individual courses	Integrative/interdisciplinary learning	Interdisciplinary knowledge
Receiving information	Active learning	Interacting and processing information
Technology separated from learning	Learning with technology	Technology integral to learning

Thus, GIS-based instruction is often done with teams of students as a project, and seems to foster inquiry-based, project-based cooperative learning, fitting the constructivist model. Even though GIS is not used by a high percentage of schools nationwide, where it is used, it is usually used in reformist ways. However, most of the lessons are not widely available to other teachers. One school teacher about to begin the first GIS class ever held at a Los Angeles high school, with 42 students enrolled in a lab equipped for 30, called for a GIS course outline on the educational GIS listserve (EDGIS-L 1999). This shows that a library of lesson plans is lacking, and respondents said plainly that this hinders their use of GIS.

Plans for Future Use of GIS

Teachers were asked, “To what extent will you use GIS next year compared with this year?” They could choose among decreasing use, maintaining present use, or increasing their use. Even though GIS cannot be quickly mastered and implemented, teachers are apparently willing to invest in making it a success. Indeed, the teachers were enthusiastic about the technology. Nearly three out of four teachers (71.9%; n=327) planned to increase their use of the software; only 4.3% planned to decrease their use (Figure 3.11). Many added comments such as "I hope!" when they circled "I will increase my use of GIS over the next year." They often wrote me personal requests for assistance on the questionnaire and via e-mail.

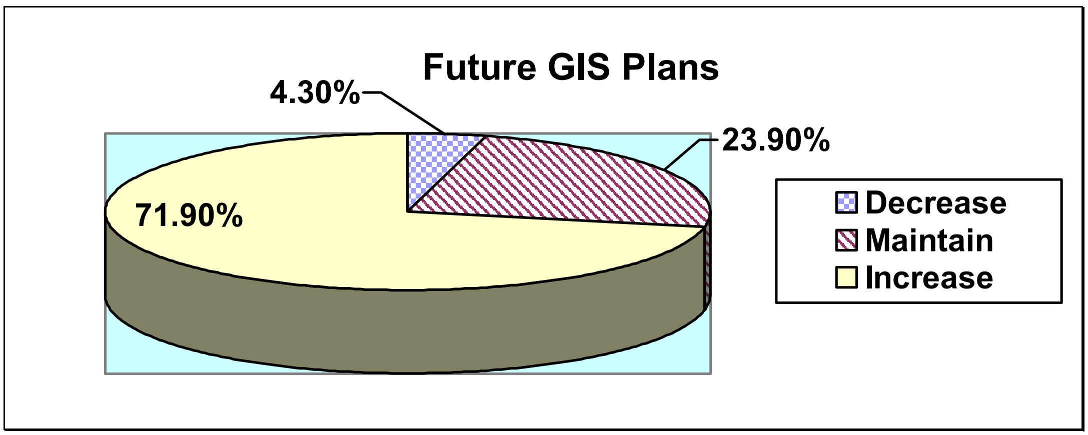

Figure 3.11. Teachers' Plans for Future Use of GIS.

The large amount of time teachers spend with GIS indicates both their enthusiasm with the tool and also the time-intensive nature of mastering and using it in the curriculum. Most teachers are so enthusiastic about this technology that they invest their *own* time to learn it. Over 62% of teachers said that they spent at least one hour per week outside of class time with GIS. Over 21% of teachers using GIS were using the tool at home. Teachers, already under pressure to perform a host of other tasks each semester, were willing to invest their personal and professional lives in this tool. The fact that most of these teachers have been in the profession at least 20 years adds significance to this finding—they are more likely to carefully consider the advantages and disadvantages to GIS, rather than "jumping on the bandwagon" of technology. Their acceptance of the tool encourages others to adopt it, rather than to dismiss it as a fad.

Most teachers (88%; n=342) believed that the use of GIS makes a significant contribution to learning (Figure 3.12). Only 1.8% of teachers did not believe that GIS made a significant contribution, and 10.2% were uncertain. Part of the explanation for the overwhelming support is because the surveys were sent to teachers who had originally expressed an interest in and obtained GIS software. There is also a natural reluctance to disclose that something a person has invested in is not worth the effort that was spent. Still, the evidence is clear that teachers, despite the challenges, believe that GIS is worth it.

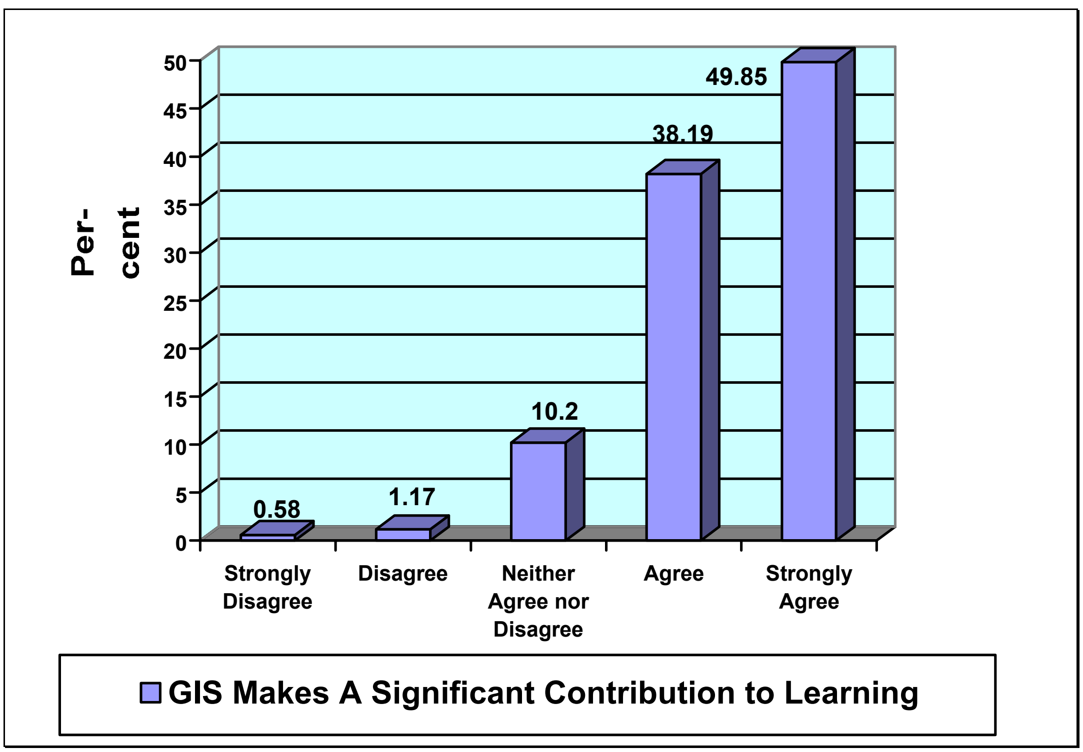

Figure 3.12. Teachers' Beliefs About the Contribution of GIS to Learning.

Constraints to GIS Implementation

Reasons for Not Using GIS

In order to discover the constraints to GIS implementation, teachers were asked to fill in the remainder of the sentence, "I am not using GIS because…" They were also asked to indicate how much their use of GIS is hindered by a listed set of constraints on a Likert scale, and to fill in the remainder of the sentence: "The most important thing that would improve my use of GIS in teaching is…"

Teachers are not using GIS because of a variety of factors, many of which point to the perceived complexity of the tool (Table 3.10). These results support the findings in the literature, which mentioned the lack of training, insufficient and poor access to hardware, complex software, and the lack of GIS-based lessons. Teachers who are not using GIS mention the lack of administrative or technical support far less frequently than those who do use GIS. This could be because teachers may only fully realize the importance of working with the technical and administrative staffs only after they implement GIS. Nevertheless, the factors mentioned below, since they are in the teachers' own words, often reveal more than those factors checked off of a list, which will be analyzed later. Comments reveal frustration—"Our school has been trying for two years to set up training." "There is too much information and not enough step-by-step." The comment "There is too large of a learning curve between uses" points to the need for ongoing, rather than one-time, training. Some cannot even load GIS in the first place: "I don't know how to use or even install it," wrote one. Another's comments summed up many teachers' feelings toward GIS: "I have not had time to deal with it." The phrase "deal with it" reveals the perception that GIS is so complicated that it will be nothing but a burden.

Table 3.10. Frequency Distribution of the Reasons Teachers Do Not Use GIS.

Reason for not using GIS	**Frequency**
Need training	35
Preparation time too long	33
Hardware problems	26
Software problems	15
Lack of access to computers	15
Difficult to implement	15
Need GIS-based lessons	8
Lack of local data	5
Lack of other teachers	2
Short class periods	2
Lack of awareness	2
Lack of technical support	1
Lack of administrative support	1
Other	13

Responses to the list of constraints to implementing GIS provided data to compute the mean (Φ) and standard deviation (σ) for each constraint (Figure 3.13).

Teachers felt that the lack of time to develop GIS-based lesson plans was the chief challenge to implementing it in the classroom. This confirms Winn, Maggio, and Wunneburger's (1996) assertion that GIS is entering the K-12 environment "without any set of resource or curricular materials...for teachers" (p. 928). These findings suggest that organizations interested in the spread of GIS (described in chapter 2) might maximize their impact on implementation by committing resources toward building these GIS-based lessons.

Constraint to GIS Implementation	Φ	σ	Degree of Constraint None 1 — 2 — Some 3 — 4 — Very Much 5
Complexity of software.	3.69	1.01	M
Cost of hardware and software.	3.13	1.34	M
Computers not accessible to my students.	3.17	1.52	M
Computers not capable of handling GIS.	3.03	1.49	M
Lack of time to develop lessons incorporating GIS.	4.00	1.14	M
Little administrative support for training.	3.07	1.43	M
Little technical support for training.	3.24	1.36	M
Class periods too short to work on GIS-based projects.	2.49	1.35	M
Lack of useful or usable data.	2.42	1.22	M
Lack of geographic skills among students.	2.54	1.09	M
Variable skill levels among students.	2.88	1.14	M

Figure 3.13. Perceived Constraints on GIS Implementation.

Next, teachers ranked the complexity of GIS software as a challenge, which was confirmed by requests (which at times were more akin to urgent pleas) for training and technical support. As with other software, GIS versions keep changing, often requiring revisions to step-by-step instructions for students. Teachers need to have an alternative plan if technology does not work, whether it is overhead projector or the GIS software. However, it is often difficult, as discovered in the case studies (Chapter 5), to emulate a GIS lesson with traditional materials. Standard deviations were relatively small for lack of lessons and complexity of GIS, indicating that teachers are fairly united on voicing concern about these factors.

Many social studies educators have had little computer training. This was made clear during the process of selecting applicants for the First National GIS Institute, where the survey questionnaire was piloted. The application included requirements that geography teachers needed to complete, such as creating a database and capturing the computer screen as an image file. Less than 50 applications were received from the entire country, and of those, several were incomplete. The organizers of the institute speculated that had the institute been targeted toward science educators rather than geography educators, the institute "would have been filled in no time" (Fitzpatrick 1998).

After teachers overcome institutional challenges, they must address implementation issues of how to modify their curriculum and instruction, and how to assess GIS-based lessons.

What teachers did not mention, but worthy of consideration, is the ability to "think spatially." Spatial analysis forms the basis for effective GIS use. It requires a thorough understanding of geographic theory in order to ask valid questions and understand the relationships of geographic phenomena. I submit that the lack of skills in spatial thinking, largely because of the paucity of geography training and background for most social studies teachers, hinders GIS use. Science teachers use GIS largely for local studies in chemistry, hydrology, and biology. They analyze the spatial and temporal distribution of measurements of water and air pollutants, wildlife, or plants. Geography teachers tend to use GIS for a wider variety of projects and scales. This is likely due to the interdisciplinary nature of their discipline, and from their social studies background, that includes economics, government, and history, as well as geography.

Besides complexity of software and lack of time to develop lessons, other factors were ranked as “somewhat” of a constraint or “not much” of a constraint. Considering that nearly half of the teachers responding to the survey are *not using* GIS, the low ratings are curious. The mean for the GIS-using teachers, or adopters, is assumed to be smaller; that is, teachers using GIS consider the constraints to be less of a hindrance to their use. One-tailed, independent-sample student’s *t*-tests with equal variances were used to determine how the mean for the adopters compared to the mean for the nonadopters for each constraint. This test’s null hypothesis is that the two samples—adopters and nonadopters—come from the same population and should have statistically similar means. However, when multiple t-tests are run, chances are higher that one of the constraints to GIS will be significantly different between the two samples. The Bonferroni inequality states that the probability of at least one of a set of events occurring cannot be more than the sum of their individual probabilities (Hamilton 1992: 143). Because 11 constraints are analyzed, instead of looking for a *t* value associated with the alpha region of α=.025, an alpha region of .025/11 = .0023 was used, which corresponds to a critical *t* of 2.86 using a table of critical values for student’s *t*-distribution (Hamilton 1992: 350). Table 3.11 summarizes these tests.

Teachers who have not adopted GIS perceived the complexity of software, incapable hardware, lack of time to develop lessons, and the lack of administrative and technical support as significantly greater constraints on implementation than experienced in practice by teachers who have adopted GIS. Although not a significant difference, the lack of skills and the variable amount of skills were found in practice by *adopters* as greater challenges than perceived by nonadopters.

Table 3.11. Differences in Perceived Constraints on GIS Implementation, Nonadopters vs. Adopters; Table of Critical t-values (* = significant at P=.0023).

	Nonadopters			Adopters			
Constraints on GIS	**n**	**Mean**	**Standard Deviation**	**n**	**Mean**	**Standard Deviation**	***t*-statistic**
Complexity of software	121	4.10	.95	199	3.44	.96	5.96 *
Hardware and software cost	113	3.15	1.40	198	3.10	1.31	.34
Inaccessible computers	112	3.24	1.62	194	3.13	1.48	.62
Computers not capable of handling GIS	120	3.48	1.54	191	2.75	1.39	4.35 *
Lack of time to develop lessons	118	4.40	1.01	196	3.77	1.14	4.95 *
Little administrative support	115	3.42	1.46	191	2.85	1.38	3.41 *
Little technical support	115	3.69	1.39	194	2.98	1.29	4.53 *
Short Classes	107	2.52	1.37	190	2.45	1.34	.43
Lack of useful or usable data	108	2.59	1.30	193	2.30	1.17	1.99
Lack of geographic skills	107	2.49	1.10	195	2.58	1.08	-.75
Variable skill levels	104	2.76	1.21	192	2.94	1.10	-1.32

To discover exactly *why* many teachers are not using GIS, or are not using it at its full potential, the response to the following question was analyzed: “What is the most important thing that would improve your use of GIS in teaching?”

What Teachers Believe Is Most Important for Improving the Use of GIS In Teaching

Repeatedly, teachers cited several items that would enhance their use of GIS in teaching (Table 3.12).

Table 3.12. The 7 Most-Cited Items That Would Enhance GIS Use.

Reason Cited	Frequency
Training	97
Time	86
Finding and Funding Hardware	49
GIS-based Lessons	43
Data	40
Hardware access	22
Networking with other teachers	21

Many teachers remarked that the general training they received was not tailored for the specific needs of the educational community: "I need a mentor who will help me actualize a project I have in mind," confessed one. Classes offered by vendors of GIS software typically "walk participants through" the components and capabilities of the software without discussing issues of implementation. Despite advances in Internet distance learning, software ease-of-use, and hardware capable of querying large spatial data sets, using GIS effectively in education evidently still requires face-to-face training and technical support. The training needs to be personalized: "I need a GIS-literate person at my elbow," admitted one respondent. Furthermore, the training needs to be of an ongoing nature—evidenced by comments such as "I lost ground when I didn't use GIS for a month, and have had to re-train myself three or four times," and "I have forgotten what I learned last summer!" This supports findings that sustained followup is critical for teachers' professional development (Loucks-Horsley et al. 1998).

The mention of time reveals the significant investment required to learn and implement GIS. One teacher, who began using it in 1993, commented *during year six* that "For the first time, I know what I'm doing." Time is difficult to assess, because it is manifest in many ways, such as time for training and time for developing lessons. However, several characteristics of time can be determined from the survey. First, time is a function of perspective. If a teacher thinks GIS is valuable, he or she will make personal and curricular time for it.

"Unlike our colleagues in colleges and universities, K-12 teachers are given almost no time to create innovative lessons or meet with their peers to discuss learning strategies," wrote one respondent. It is difficult for teachers to learn GIS software in the one planning period per day that they typically receive. One teacher recalled a storm that isolated her from distractions in her snowbound home for several days, allowing her to learn GIS for the first time. The survey found another respondent in the midst of a year-long sabbatical, taken specifically for the purpose of learning GIS. Still another teacher who had to take a semester off wrote that "I have had the software for two and a half years, and I have barely set up a file."

Frequent mention of time also reflects the dearth of GIS-based lesson modules, because if they were readily available, teachers could modify them just as they do to other existing lessons. Teachers implementing GIS are often simultaneously developing and implementing the curriculum. One teacher wrote that to modify just one lesson in a GIS environment required over 15 hours. Another wrote, "It will take a massive and time-consuming effort to produce these lessons." Teachers who design GIS-based modules must also list the sources of software and data, and make certain that students will be able to access the associated spatial data. The number one recommendation from the first national conference on educational GIS was the need for the development of GIS-based lesson modules (Barstow et al. 1994). Six years later, the need still exists.

One respondent wrote that he would be developing standardized step-by-step lessons to bring GIS to the core curriculum of all 21 geography sections at his high school. However, this was only after the respondent had been using GIS for three years. While he still saw a place for special projects, he recognized that without these standardized lessons, the school district would cut their support for GIS. Otherwise, they would see it as a "specialty item for one teacher." According to him, GIS needs to be "packaged right" in order to spread throughout the curriculum.

Finding and funding hardware is another limit to implementation. *ArcView*, for example, requires a Pentium PC with 32 megabytes of random-access memory (RAM) to run effectively. Its extensions such as *Spatial Analyst*, *Image Analysis*, and *3D Analyst* require 64 or more megabytes of RAM; ideally, 132 megabytes. Most schools order computers with far less memory, since few other software packages require as much RAM as GIS software.

Based on the survey data, better hardware will not always solve the problem. One teacher wrote that although she had a brand new Pentium-2 laboratory with computers of 450-megahertz speed and 16-gigabyte hard disk drives, she received "segmentation violation errors every day on different machines with different students." GIS tests computer systems as few other software packages do.

"I feel I'm on my own—an overwhelming thought," wrote one teacher, expressing a desire to network with others. Eleven teachers stated that they required "user-friendly" software, which is not surprising, considering that the GIS software used by schools is the very same set of software in use by government, business, and industry to perform complex spatial analyses. One teacher expressed his frustration by imploring: "Simplify the software! Darn you engineers—design it for real people, please." Other teachers mentioned that data specific to their project would improve their use of GIS: "We are at the stage of identifying the sorts of data sets that teachers need to use GIS. For many of them, this is a bit of a fearsome thing and I am looking for materials that will prevent us from reinventing the wheel."

Since few (11) teachers listed that the software was too difficult, and no teacher mentioned computer training as top priority, the teachers using GIS must have confidence in their computer ability. They must have had sufficient background in computing to feel comfortable with using a *system* of technological tools. This supports Okinaka's (1992) survey showing that exposure to and education about computer technology seemed to be primary issues in stimulating computer use by teachers. This also supports Rosen and Weil (1995), who found that between one-third and two-thirds of 488 surveyed teachers did not use computers extensively because they lacked confidence or felt uncomfortable. Feeling confident about one's computer use, or at least being open to learning something new, seems to be a major encouragement to using GIS. Teachers' comments indicated their interest in improving their use and the student's use of technology. Teachers frankly admitted that they were intent upon improving this ability, even if it were just for technology's sake. In other words, the mere fact that GIS technology existed was reason enough to learn about it and develop skills with it.

Only one teacher indicated that the most important thing that would improve GIS use is evidence that GIS is effective in the classroom. Evidently, teachers responding to the survey do not find this evidence as important as the abovementioned factors, or perhaps they already believe GIS is effective. However, the lack of administrative support reported by teachers may be partly due to a lack of evidence. Furthermore, the kind of teachers who need this evidence are not likely to be the survey respondents, because those who described their lessons are already convinced of the utility of the technology. Empirical or case study evidence might be interesting to these teachers, but it is unlikely to sway their future use of GIS. Rather, evidence is more likely to influence teachers who are undecided about whether to implement GIS.

Finally, teachers did not state that they lacked the content background in geography to effectively use GIS. This background is essential because GIS rests on geographic concepts of scale, location, coordinate systems, projections, and spatial analysis. Teachers must feel confident in their abilities to use GIS, or, perhaps more commonly given the high percentage of nonadopters, are not aware that these spatial concepts are necessary to make effective use of GIS.

Benefits of GIS Implementation

In order to understand teachers' perceived benefits to implementing GIS, they were asked to complete the sentence "I decided to use GIS because…." They were also asked to indicate how much their use of GIS results in a listed set of benefits on a Likert scale, and were asked to finish the sentence: "The most significant thing that I have accomplished with GIS in the past year is …"

The integration of any technology is driven by a variety of factors, such as the existence of a district or state technology plan, accreditation, peer expectations, student expectations, and whether teachers are evaluated on how they use technology. Motivation and perceived benefit are linked. Teachers decide to implement GIS most often because they want their students to understand data, the relationships among data, and to be able to perform spatial analysis with those data (59 respondents). "Some of our science projects are much more understandable when the data is [sic] analyzed spatially," wrote one teacher.

Next most often, because GIS is a tool developed and used in the professional world, teachers feel obligated to use it (55 respondents). They write as if they have no choice; that the advancements in technology require them to use GIS. Teachers would feel remiss if they withheld from their students a tool that will, in the words of one, become “the word processing of the next decade.” Another wrote:

> “My school’s philosophy, which also happens to be my philosophy, is that education should be applicable. The students will be more willing and eager to learn if they see a purpose. GIS is the answer. It makes the social studies something other than the study of dead people and strange places.”

Others mentioned that “it is the way we will do business in the future,” that it will “become a household word,” and that GIS “is one of the most far-reaching technologies available.” One teacher responded with “As a geographer I believe it [GIS] is an essential tool for 21st century geographic instruction.” Repeatedly, teachers praised the “practical” aspects of the GIS—that it was “technology with a purpose.”

Many teachers (33 respondents) began using GIS because they became “hooked” on its technical capabilities. “I was wowed by it” wrote one teacher. Another wrote that someone said “You should sign up for this free teachers workshop.” Then “I went and I was hooked.” GIS convinces some teachers who are not computer users to embrace computer technology—“Finally I have found a good use for the computer in the classroom” wrote one teacher. Clearly, GIS contains some unique capabilities that captivate teachers’ interest.

Comments such as “it is worth the pain and suffering because it has a fantastic potential and the future applications are tremendous” show two things. First, the words “pain and suffering” show that GIS is perceived as truly difficult, but also, teachers are willing to work through challenges to implement it. It must be remembered that most teachers responding to the survey are not using GIS. If most teachers who have seen demonstrations of the tool are using GIS, it follows that many nonadopters might implement GIS if they could see a live demonstration of it.

This has implications for the amount and type of training that should take place for implementation to increase.

Teachers often mentioned (31 respondents) that they are using GIS because they had a specific task that they thought GIS could accomplish. GIS meets their need, whether it is analyzing local wetlands or global demographics. The visual capabilities of GIS were often mentioned (27 respondents). Specific job opportunity skills fostered by GIS impelled some teachers (23 respondents) to implement it. One teacher mentioned that 50 of his students worked in GIS for the school district over the summer at $10 per hour. Other teachers are using GIS because they are required to do so by a funded grant (23 respondents). Teachers mentioned that they decided to implement GIS because of its interdisciplinary applications (13), critical thinking advantage (11), ability for students to analyze local data (9), because they were exposed to it in the past (8), or because of its project-based learning opportunities (6).

Only one teacher decided to implement GIS because of the educational content standards. If teachers do not believe GIS can help them teach the standards, and are increasingly required to teach standards-based lessons, this reveals an important constraint on GIS implementation.

Responses to the list of perceived benefits to implementing GIS indicates further perceived benefits and the motivation teachers have for implementing it (Figure 3.14). Teachers felt that the most important benefit that GIS brings is real-world relevance to curricular areas (mean=4.14). This is evident in the reasons listed for why they decided to use GIS, with repeated mention of specific projects based on local areas for students to analyze.

Benefit to GIS Implementation	Φ	σ	Degree of Benefit: None 1, 2, Some 3, 4, Very Much 5
Helps teach national, state, or district standards.	3.05	1.35	M
Enhances Learning.	3.97	1.07	M
Provides exploratory tool for data analysis.	4.06	1.17	M
Provides employment skills.	3.32	1.34	M
Offers team learning environment.	3.58	1.25	M
Provides real-world relevance to subject.	4.14	1.13	M
Provides integration of different subjects.	3.72	1.17	M
Provides opportunities to partner with community.	3.46	1.41	M
Enhances motivation and student interest.	3.95	1.13	M

Figure 3.14. Perceived Benefits of GIS Implementation.

In many GIS lessons, a hypothetical scenario is put into effect. For example, students use a digital elevation model to compute how much of New York City would be under water if the sea level rose by different increments. What student wouldn't feel powerful and confident after he or she "flooded" an entire city? These feelings raise motivation and interest. Students are aware that they are using the same tool as in industry, rather than software written for high school students, and are inherently more enthusiastic about using it. "These kids are never out of my room; they show up at 6:00 a.m.," wrote one teacher. Confirming increased motivation and integration of different subjects, one teacher enthusiastically shared her experience during an educational portion of a state GIS conference. Two sophomores she brought to the conference said to her, "Do you understand the implications of this technology in teaching U.S. History? We could use this to fully understand the topography of the land relating to the battles!"

The lowest score, and the only benefit scoring near “3” (“some benefit”) was “helps teach national, state, or district standards.” As indicated in the analysis of benefits, even though published research links standards to GIS use, if teachers do not *perceive* that GIS is a good standards-based tool, its implementation will be hampered.

Responses indicate that teachers are using GIS to enhance content areas such as science and social studies (teaching *with* GIS), rather than teaching an employment skill (teaching *about* GIS). Employment skills and marketability are mentioned, but these are side benefits, not the main goal. One teacher mentioned that after a GIS presentation, one of her students was offered a $30,000 per year computer technology job while still a sophomore at her high school.

Teachers detected improvements over time, both in their student’s ability and in their own ability: “It amazes me how little time I spend on teaching the *ArcView* technology now. I used to [two years ago] spend 4 weeks of instructional time before we could start doing analysis. Now I am down to three long (1.5 hours) class periods,” wrote one respondent. Students are usually less wary of using new technology than teachers. “[Students] don’t know they can’t do dynamic segmentation and all that exotic stuff, they just do it” (Environmental Systems Research Institute 1995).

Overall, teachers gave higher rankings to benefits than the rankings they gave to challenges (means were 3.69 for benefits vs. 3.06 for challenges), reflecting their enthusiasm for the tool. No mean benefit was less than 3.0 (some benefit), while means for four challenges were under 3.0.

Accomplishments with GIS

The most significant accomplishments over the past year that teachers listed reflects the constructivist nature of GIS-based methods, challenges in implementation, the dedication of the implementing teachers, and connections with the community.

The bulk of responses to this question indicate that teachers recognize that GIS is a long-term, lifelong learning process. Only one teacher felt as if he had “mastered” the software. Most teachers felt that their most significant accomplishment was simply “continuing to learn more about GIS,” or developing a data set that they plan to use “someday.”

Responses tended to focus on personal benefits, rather than benefits to the students. These benefits confirm their decision to adopt the technology, encouraging them to continue. This supports Caffarella and Hall’s (1999) application of the diffusion model to education, which emphasized that confirmation was key to the innovation decision process. Research on innovation suggests that the more compatible that ideas are to the existing values and norms of a social system, the more likely it is that they will be adopted (Rogers 1995). Survey results were consistent with research findings that innovations are more readily accepted when considered as being of value to a person in the system rather than stressing the value of the principle itself.

Most teachers were pleased just to “become aware of GIS” and “start using it,” although the feeling wasn’t shared by everyone: Two teachers wrote that “frustration” was their significant accomplishment for the year. Another wrote, “I am currently attempting to teach 136 freshmen how to create an island using [*ArcView*] 3D Analyst (SCREAM!)” (upper-case letters preserved from original quote).

Many responses equivalent to "just getting the software loaded" reflect significant computer challenges associated with this technology. One teacher wrote that she is "burning up a lot of time with nothing to show for it." If the most a teacher can do with GIS over a whole year is just to load the program, then either the software is inherently complicated, or teachers do not have adequate training in technology. I submit that it is both. Furthermore, because the technology supports data sets developed in multiple projections and dates, by multiple methods, by multiple organizations, and must manipulate thousands of pixels of satellite imagery or segments of river, there is an inherent complexity of the technology that requires ongoing technical support.

Instability is an inherent part of any organization. In schools, instability is manifest in staff changes, computer upgrades, administration changes, standards changes, and a host of other change agents. If GIS lessons and data require so much time to prepare, what happens if all or part of the staff developing these capabilities move to another school? Because the survey revealed that GIS has not been institutionalized nationally, it is likely that the GIS program would cease temporarily or permanently at the original school. It is also likely, given the zeal these teachers have for the technology, that they would implement it at their new school. Indeed, six teachers from the pilot test group transferred to a different school over the following year. In all cases, the teachers brought GIS to their new schools. Lessons might be modular and sustainable within a school, but are not easily transferable to different courses, computers, and schools. On the other hand, the comment of one teacher was "[GIS] is a mission. I won't leave the district until I have two or three other [teachers] to continue it." At Shelley High School, Idaho, a teacher found himself the "inheritor" of a GIS program after the developing teacher left (McGarigle 1999a). The inheriting teacher developed a student-mentoring program where experienced GIS students taught him the basics, and taught new students.

Responses to the “most significant accomplishment” question confirm anecdotal accounts indicating that teachers using GIS tend to be connected to their communities to a greater extent than are non-GIS teachers. One teacher found an aerial surveying company that possessed the photographs of his town for the last 40 years. He also obtained the data for all building footprints from the city planner, and used the two sources with his students to show city growth over time. He also obtained a complete tree inventory of every specimen along the local river for his field biology students to measure their properties, adopt a tree, and perform statistical analysis.

Another teacher combined computer technology with environmental issues and fieldwork, where students collect soil, vegetation, topography, and water quality data for the school campus. The school has become a clearinghouse for digital information on their watershed, and many agencies call on them to provide maps and analyses using their GIS database.

A teacher who began a GIS course at a high school was amazed to find that over 70 students had signed up. Students could obtain credit at a community college by taking the course. The same teacher brought 12 other teachers and 120 students to the state GIS conference, and was then invited to speak with several of her students at the State Legislature about how she used a $76,000 state creative teaching grant.

Several students in another class provided an overview of water quality on the global, national, regional, and local level through a series of GIS-based presentations at the County Water Quality Monitoring Congress. The teacher wrote, “If I do say so myself, that was pretty impressive. The important thing was that the students had the opportunity to present to a live audience, talk to the press about their work, and show other teachers and students what is possible with computers in general and *GIS* in particular." The teacher meets with a county GIS roundtable to develop a network of data producers and users.

Evaluating Implementation Models

GIS Implementation Models

Audet and Paris (1997) proposed a GIS implementation model based on a survey of 45 schools (Figure 3.15).

Do the results of this dissertation's national survey fit this model? Hardware and software concerns were generally high, indicating that most schools are in the initiation stage of the implementation process. Concerns about data were higher in schools that were in the "development" stage, consistent with the model. Concern about developing educational lessons was high, which does not appear at first to fit the model. However, *relative* to the time spent on learning the software and installing the hardware, lesson development was likely to be small. However, a separate question on this point was not asked, so one can only speculate.

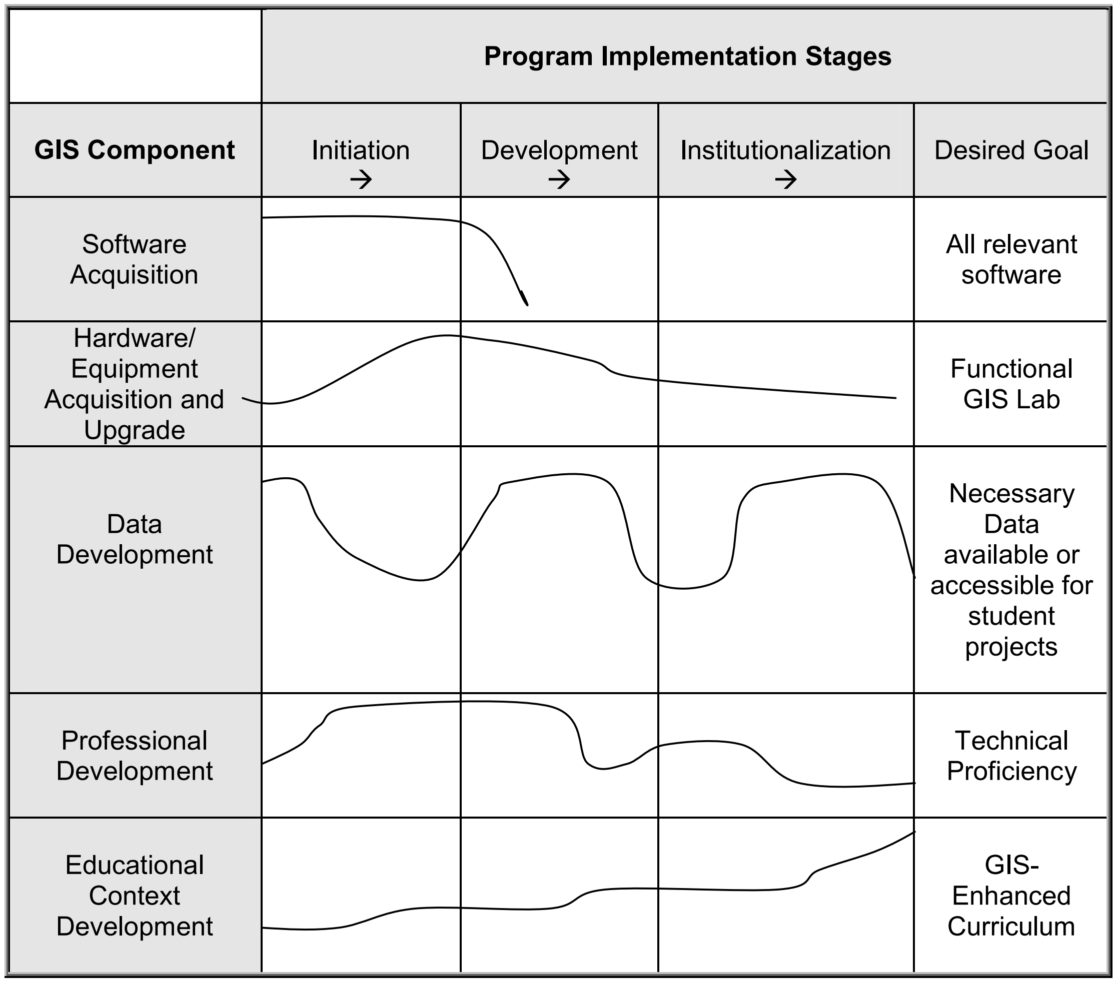

Figure 3.15. GIS Implementation Profiles, from Audet and Paris (1997: 296).

The height of the lines inside the table indicate the relative amount of effort expended on that particular GIS component. For example, effort in software acquisition is high initially and then drops off, while data development tends to occur with the start of a new GIS-based project.

Audet and Paris described institutionalization as programs that had a "well-developed educational context and were likely to continue even in the absence of the program initiators" (p. 294). As both the literature review and the survey made clear, GIS in education has not yet been institutionalized. For most teachers, implementing a few *lessons* rather than implementing a *curriculum* would be a more accurate statement. Few teachers felt technically proficient, again indicating that few schools were at the institutionalization stage. The survey made it clear that there is no single entry point in GIS implementation. Multiple pathways, methods, and curricula exist. This model will be further tested against the three case study schools in Chapter 5.

Multiple regression with the degree of GIS implementation as the dependent variable was run to determine the effect that independent variables had on implementation. The “degree of GIS implementation” refers to the categories in Table 3.1 (page 90). The number of training hours, the number of years a teacher had been teaching, the number of teachers using GIS in the school, the amount of technical and administrative support, and the number of conferences the respondent attended each year were used as independent variables in the model. The R^2 value was .3030—the model explained about one-third of the degree of GIS use (Table 3.13). The number of teachers using GIS in a school had the highest *t* value, indicating that one can have more confidence that this variable affects the amount of GIS use in a school more than any other. The implication for training is that GIS will more likely be institutionalized in a school if teams of teachers from the same school are trained at the same time. Because time spent in GIS training was the next most influential variable, training programs are critical if teachers are going to use this technology. After teachers are trained, technical support in the school is a significant factor. Administrative support was insignificant in determining implementation—these teachers use GIS regardless of the support they receive, though they admit that support would aid their efforts. Although many teachers using GIS are veteran teachers, the number of years of teaching was not significant for determining the amount of GIS implementation in this model. GIS-using teachers are active, evidenced by the significance of the numbers of conferences they attend per year.

Table 3.13. Multiple Regression Model of the Degree of GIS Implementation.

Multiple Regression Model of the Degree of GIS Implementation $R^2 = .3030$ N=270 F(6, 263)=19.05			
Variable	**Coefficient**	**t-statistic**	**P**
Hours Spent in Training	.4061	4.171	0.000 *
Number of Years of Teaching	.0588	0.718	0.473
Number of Teachers Using GIS in the School	.6178	4.564	0.000 *
Amount of Technical Support	.3892	3.301	0.001 *
Amount of Administrative Support	.1256	1.078	0.282
How Many Conferences Attended Each Year	.4376	2.358	0.019 *
Constant	-.7731	-1.168	0.244

A correlation matrix was generated for the same variables (Table 3.14), which allowed analysis of relationships between variables. Younger teachers were more likely to be in a team of teachers than older teachers and receive more administrative support. Administrative and technical support were associated, as were administrative support and training hours.

Table 3.14. Correlation Table of the Degree of GIS Implementation.

Variable	Degree of GIS Use	Training Hours	Number of Years Teaching	Number of Hours in Training	Amount of Technical Support	Amount of Admin. Support	Conferences Attended/year
Degree of GIS Use	1.000						
Hours in Training	.3606	1.000					
Number of Years Teaching	.0052	-.0431	1.000				
Number of Hours in Training	.3986	.1904	-.0635	1.000			
Amount of Technical Support	.3350	.1638	-.0480	.2805	1.000		
Amount of Admin. Support	.3256	.3032	-.1771	.3633	.4696	1.000	
Number of Conferences Attended/ year	.2291	.2288	.1183	.1556	-.0020	.0702	1.000

Diffusion of Innovations Model

Rogers' (1995) diffusion of innovations model can be applied to the implementation of GIS at the secondary level. Rather than simply evaluating the technical worth of the innovation, this model emphasizes uncertainty regarding the consequences of adoption of the innovation, the importance of communications to provide information about the advantages and disadvantages of an innovation, and the dependency of speed and extent of diffusion on political and social processes. Since no empirical data existed on the effectiveness of GIS on learning, teachers proceed with implementation in an uncertain environment. They seek software support, and, more subtly, confirmation of their efforts among the small band of other teachers implementing it. Therefore, despite their solitary work within their schools, most communicate fairly regularly with other teachers who use the same software, so that they can share both technical advice and lessons. Thus, the network size and boundaries of GIS-using teachers tend to be defined by software type. Because of the complexity of the software and the unique nature of each, it is extremely rare to find a teacher conversant in more than one GIS software package. Communication occurs most frequently between individuals who are alike. *Homophily* (Rogers 1995) is the degree to which a pair of individuals who communicate are similar (p. 286). GIS- using teachers have a keen sense of the very special nature of their work, and the influence they believe it will have on the future of education and on student learning. Despite a wide variety of personalities, they have developed close personal as well as professional ties with each other (Bednarz 1999). These ties cut across grade levels, and include primary, and to a lesser degree, college-level educators.

Although the speed and extent of diffusion of GIS in education has recently increased, it experienced slow growth throughout the 1990s. Therefore, its effect on political and social processes has not been widely felt, but GIS-based methods could potentially spread reform beyond secondary education.

Rogers (1995) defined five characteristics of innovations that help explain their rate of adoption—relative advantage, compatibility, complexity, trialability, and observability. *Relative advantage* is the degree to which an innovation is perceived as better than the idea it supersedes. GIS is perceived by a small group of teachers to be advantageous over other methods and technologies, but the large majority of teachers are not even aware of its existence. *Compatibility* is the degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs. As explained in this chapter, full use of GIS requires constructivist methods of instruction. It is perceived as consistent with the instruction of only those teachers who were constructivist teachers to begin with, or are willing to adopt constructivist methods into their teaching. *Complexity* is the degree to which an innovation is perceived as difficult to understand and use. *Trialability* is the degree to which an innovation may be experimented with on a limited basis. Complexity and trialability clearly work against GIS adoption—it is difficult to use, and historically has been difficult to try. Software such as *ArcVoyager* and Internet-based map servers are finally making trialability a realistic option. *Observability* is the degree to which the results of an innovation are visible to others. Teachers using GIS have been very active in speaking at conferences, but mostly to educators within their own discipline. GIS use is not yet widely visible to the educational community as a whole.

The rate of adoption of a technology is dependent on how the above five attributes are perceived. The rate is also dependent on the communication channels, whether the type of innovation decision is optional, collective, or from an authority, the nature of the social system, and the extent of change agents' promotion efforts. Deciding to use GIS is optional, and the fragmented nature of the K-12 educational system hinders communication within and among schools.

A critical mass occurs at the point where enough individuals have adopted an innovation that the innovations' further rate of adoption becomes self-sustaining (Rogers 1995: 333). As more teachers adopt, it is perceived as increasingly beneficial for future adopters (sequential interdependence) and for each previous adopter (reciprocal interdependence). GIS has not yet reached this critical mass, and at the rate it is proceeding, will not have achieved critical mass for perhaps a decade. Therefore, implementation will, for some time to come, require a great deal of support from the non-educational organizations mentioned in Chapter 2.

In the diffusion of innovations model, change agents influence innovation decisions, develop a need for change, develop information exchange relationships, diagnose problems, create the intent to change, stabilize adoption, prevent discontinuance, and achieve a self-renewing behavior. Are the high school teachers who are implementing GIS “change agents?” The goal for most teachers is to improve what happens in their own classrooms. Even so, they do act as change agents, because their actions match those described above. As their innovation is put into more widespread use in the educational system, the meaning of the innovation becomes clearer to others. This, known as *clarifying*, is underway in American high schools, albeit very slowly. In contrast, *routinization,* which occurs when the innovation has become so incorporated into the regular activities of the organization that it loses its separate identity (Rogers 1995: 404), has yet to occur. GIS is still viewed as something outside the educational mainstream.

Three sets of variables determine whether and when an individual will adopt an innovation—socioeconomic status, personality, and communication behavior. GIS educators are intelligent and motivated, able to cope with uncertainty, and communicate often. Unlike the model, however, rather than being the typical young innovators, they tend to be veteran teachers.

By and large, the amount of *reinvention*—the degree to which an individual’s use of a new idea departs from the mainline version of the innovation—is low. Teachers have fewer restraints on their use of GIS than users in industry and government, and thus can be creative with the software. However, they are usually using the software in the way it was intended—for spatial analysis. Because the sheer number of teachers employed in the United States dwarfs the number of transportation planners, engineers, natural resources specialists, and other GIS users, the potential exists for educators to exert a great deal of influence over the industry. Teachers have already been influential in the development of *ArcVoyager*, a set of tools designed for educational users of *ArcView* software.

Innovation Decision Process

Caffarella and Hall (1999) modeled the innovation decision process as five stages—knowledge, persuasion, decision, implementation, and confirmation. Regarding GIS, most teachers are not even at the "knowledge" stage. These authors also classified adopters into categories with a chief characteristic for each—Innovators (venturesome), early adopters (respect), early majority (deliberate), late majority (skeptical), and laggards (traditional). They claimed that, over time, the non-adopters will shrink in size, adopters will increase, and rejecters will stay the same in number. The non-adopting teachers may be awaiting more evidence as to whether GIS will be worth the time and effort, or may adopt after it is so embedded in the mainstream that their actions will be considered "traditional." One reason for the gap between the early adopters and the mainstream is that school structures (such as class period length) have not been changed to accommodate the differences between the two. The mainstream adopters require a system that supports the innovation, unlike the early adopters, who find ways to make the new innovation work in the current system.

Social Interactionism

Social interactionism (Campbell and Masser 1995) is another model that fits GIS in education. This model emphasizes how an innovation is affected by the culture of the organization. GIS is affected by the culture of schools. Therefore, there will be both "winners and losers" with the ultimate balance determined by the specific circumstances. The "winners" are those who are successful in their implementation efforts. A circular process exists—teachers use the tools, become successful, which encourages them to use more tools.

Social interactionism states that the reason for adoption is to enhance symbolic status or power. Although technology is not value-neutral, the survey did not indicate that teachers enhance their status through GIS. Indeed, they usually *give up* control, because they are using a new tool and method, allowing their students to take more control over their own learning. Since most teachers do not receive any special benefits from using technology by their administrations, they take on additional responsibilities—such as troubleshooting computers—without being compensated. Reward systems associated with learning and using new technologies are weak. Teachers are usually commended by administrators for the *amount* of content they cover. They cannot teach as much content if they spend time exploring topics in depth with a GIS.

Predictors of GIS Implementation

GIS Predictors: Teacher Characteristics

Fitzpatrick (1999a) proposed four predictors that determine if GIS will be effectively implemented by a teacher: (1) Strong file management skills on a computer; (2) a strong grasp of computer databases; (3) is comfortable doing their own personal exploration in "un-bounded" tasks that lack definitive paths, and comfortable modeling this behavior for others; and (4) is comfortable permitting students to engage in these tasks that lack definitive starting and ending points, concrete paths, and predictable results. While these were not tested directly in the survey, teachers using GIS repeatedly mentioned the phrases "exploration," "investigation," and spoke of data manipulation with spreadsheets and databases. It appears as though these predictors are characteristics of GIS implementers. These predictors will be further examined in the case studies.

> "People ask [me] every day 'How long will it take me to learn GIS?' I always cringe when I hear that perfectly legitimate question. Even once a teacher has a strong handle on the basic procedures, they might not know what to do with it. If they have strong spatial sense but low on …the four [key] predictors, they don't seem to use the tool effectively, because they can't find the data, don't know what can be done with the data, don't spend time exploring multiple pathways personally, or aren't willing to let the class work with an activity with unpredictable results. Spatial thinking requires time." (Fitzpatrick 1997c).

One respondent estimated that out of 3,200 teachers in their district, only 25 to 30 teachers could match the four predictors, and most of those were already involved in a number of other legitimate programs.

I submit that an ability to think spatially should be added to the four predictors. Otherwise, teachers can be taught the tools, but if the tools have no meaning, they won't be effectively used. Another predictor that should be added is whether a teacher has an implementable use for the tool—if they can envision an application and a need for GIS. The analysis in Chapter 5 confirms that this was one key reason why the technology was adopted in the case study high schools. The richness of the content is pivotal because it is through the course content that the possibilities of implementation in lessons exist. Teachers should use GIS as soon as possible after they are trained. Many respondents expressed frustration for forgetting what they learned earlier.

Requirements for Effective Use of Technology

David (1994) recognized four requirements to the effective use of technology: functionality, professional development, access, and technical support. Only one of these is a technological rather than a social issue. GIS is no different. Hardware and software were significant factors influencing the implementation of GIS, but were less important than training, perception, time constraints, and spatial thinking.

Four Stages to Learning

Binko (1989) identified four stages to learning: awareness, understanding, guided practice, and implementation. Based on this study's national survey, awareness seems to be the first and largest obstacle to teachers learning about GIS. Confronted with an ever-expanded array of multimedia resources, teachers face more options that compete for a constant amount of contact time with pupils. The survey indicated that once they see a demonstration of GIS, teachers will want to implement it, at least to some degree. According to these data, the only way GIS will be institutionalized in education is if more demonstrations and training can be conducted.

Top-Down versus Grass-Roots Efforts

The nature of GIS in education is probably having more benefit in terms of student learning as a grass-roots effort than it would have from a top-down approach. Studies have shown that top-down technological innovations are seldom successful in education (Audet and Paris 1997; Tyack and Cuban 1995). Teachers will not adopt the technology unless they believe it will have a positive influence. Those who have adopted the technology are convinced of its benefit. However, this grassroots nature slows the rate of implementation.

GIS has been infused into secondary schools, with hundreds of GIS software licenses. However, true integration is the process of combining the use of computers into the existing curriculum through learning activities that address the subject-area objectives (*Electronic Learning* 1988). GIS has not yet been integrated, according to this definition.

Summary

For nearly three decades, GIS has been capable of analyzing complex phenomenon from local-to-global scale, both spatially and temporally, in an interdisciplinary environment. However, this study's national survey revealed that GIS has not made significant advancements in terms of the number of secondary schools using it. Over 500,000 users of *ArcView* GIS exist worldwide (Environmental Systems Research Institute 1999b), but less than 1,500 were in the database of educators. The number of high schools owning one of three main GIS software packages numbered less than 1,900, representing fewer than 5% of all secondary schools. Even among teachers who own GIS software, nearly half are not using it.

To put it another way, the state of the *art* is far beyond the state of *practice* (Means 1994). Not many examples of full integration of GIS technology and methods were found, but this is consistent with other technologies. Only 3% of schools in the U.S. are effectively integrating technology into all aspects of their educational programs (according to Viadero 1997b).

GIS is being implemented in standard-sized schools and classrooms, primarily by veteran science teachers. Although technological and administrative support is lacking, teachers who have adopted GIS are enthusiastic and active. Lessons are constructivist, reformist, and interdisciplinary in nature, emphasizing teaching *with* GIS in a content area, rather than teaching *about* GIS. Implementing GIS is a complex process, evident in such survey data as lag periods of up to several years between the time teachers obtain GIS software and the time they implement it. Teachers are first trained in GIS largely through inservices. Preservice teachers have little opportunity to learn about GIS. Positive factors in implementing GIS fall mostly on the learning side, while on the teaching side, some are negative. A lack of education-specific training, time to prepare lessons, and the complexity of the software are the chief challenges to implementing GIS. Providing real-world relevance, integration of different subjects, providing an exploratory skill, and enhanced learning and motivation are cited as the main benefits.

There is no mandate requiring the use of GIS in the educational curriculum. However, a small percentage of teachers nationwide have taken it upon themselves to not only use it, but solve problems and conduct workshops to promote its implementation. Convinced of its benefits, these teachers amount to about 15% of survey respondents, and spend a great deal of personal time with GIS.

GIS implementation was examined through a GIS implementation model by Audet and Paris (1997), through Rogers' (1995) diffusion of innovations model, and a social interactionism model. Predictors of GIS implementation in education include good computer file management and database skills, and comfort in giving students the freedom to explore in class. I suggested that spatial thinking and the existence of an implementable project be added to these predictors. The survey showed that the best predictor of a teacher using GIS is if more than one teacher in the school is using it, followed by the number of hours spent in GIS training.

Because GIS is being implemented largely by individual teachers, there may be principles of instructional materials development that are not being incorporated into preparing curricula. These include multiple intelligences, cooperative learning, and the learning cycle. The only exception found was NSF's "GIS Access" project, which uses the "active learning" model as a guide. However, this project's emphasis is on training, not on lesson development. Other curriculum development projects in geography, such as the NSF-funded "Hands-On Geography" project, active learning modules on human dimensions of global change, and the "Virtual Geography Department" effort to place high-quality college geography lesson modules on the

Internet follow curricular guidelines that are largely absent with GIS lesson development. These inquiry-based, standards-based projects provide suitable models for developing GIS lessons, but developers of GIS-based lessons usually do not follow a common framework. Most of these GIS-based lessons are not widely available or easily used by most teachers, inhibiting the speed of GIS diffusion throughout secondary education.

One teacher conducting a peer training session commented that at the end of the training, a teacher asked, “Can I print out blank outline maps with this program?” This shows that some teachers view GIS as nothing more than a computerized atlas. Thinking in a different way is perhaps the one factor that hinders GIS implementation in education the most. With advances in accessibility of hardware, software, and data, learning is increasingly dependent on the adaptability of teachers more than accessibility of technology. Powell’s (1999) study found that although innovative science curriculum materials do influence teachers’ practice, even more important is whether a teacher’s beliefs are aligned with the philosophy of these curriculum materials. The implication for GIS is that only those teachers who value an open-ended, exploratory approach to learning will adopt it.

Clearly, GIS is not the type of tool that a teacher can implement into the curriculum as soon as it is obtained, nor can it be easily expanded in the curriculum. This is the irony of GIS—if it were “plug and play,” more teachers would use it, but much of the functionality and flexibility would have to be removed. This would make it less of a constructivist tool and more of a traditional one. GIS is not Aplug and play” because it is an exploratory tool. Upon accessing GIS software on a computer, its graphical user interface appears, framing one or more empty windows. The software requires the user to make the choices about the type of data, the geographic extent, the scale, and the amount of data to analyze. These blank screens are daunting to the first-time user. The tool itself has no answers—these come from human operators. If the answers were readily available, then the students would not be *constructing* them in a problem-solving mode, but simply using a computer to amass facts as they do using textbooks.

The national survey confirmed the literature review's discovery that despite the presumed utility of GIS tools, a wide gulf remains between the capability of the tools and the implementation of the tools.

Having analyzed the implementation of GIS in secondary education on a national level, the next two chapters address its implementation and effectiveness on a local level. Implementing GIS and engaging students with computers does not necessarily mean that students are learning anything important or relevant. Experiments were conducted to assess the effect of GIS on learning. The local study involves a series of experiments and case studies within three high schools.